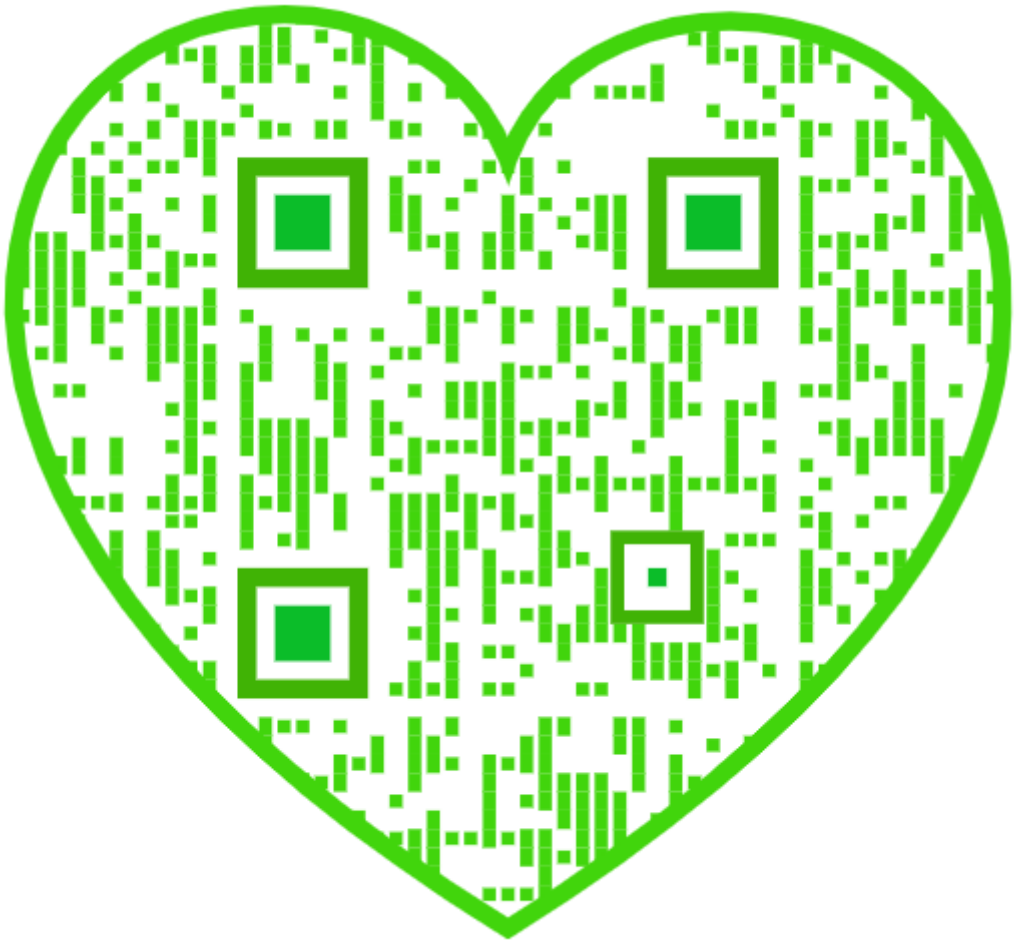

A

# TREATISE

ON

## GUN-POWDER, FIRE-ARMS,

*&c. &c. &c.*

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# A TREATISE ON GUN-POWDER;

# A TREATISE ON FIRE-ARMS;

AND A

TREATISE on the SERVICE of ARTILLERY in TIME of WAR:

TRANSLATED FROM THE ITALIAN OF

ALESSANDRO VITTORIO PAPACINO D'ANTONI,

Major General in the Sardinian Army, and Chief Director of the Royal Military Academies of Artillery and Fortification at Turin.

*By* CAPTAIN THOMSON, *of* The Royal Regiment of Artillery.

LONDON:

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MDCCLXXXIX.

TO HIS GRACE,

# CHARLES,

## DUKE *of* RICHMOND,

## LENNOX, *and* AUBIGNY,

*&c. &c. &c.*

MASTER GENERAL

OF THE

ORDNANCE.

MY LORD DUKE,

THIS tranſlation has more than a common claim to your Grace's patronage; for, to whom could a work, compiled expreſsly for

the inſtruction of young men deſtined to ſerve in the artillery, be with ſuch peculiar propriety inſcribed, as to your Grace? under whoſe auſpices the Royal Military Academy has attained a pitch of excellence, that promiſes to the Sovereign and nation, whoſe bounty ſupports it, an ample compenſation in the knowledge and talents of the ſtudents.

The æra of your Grace's command of the ordnance has been diſtinguiſhed by many ſalutary reforms and uſeful regulations;

regulations; and by an attention to every thing that can tend to the advancement of the public ſervice, or the promotion of ſcience: I have, therefore, preſumed to dedicate this tranſlation, the employment of my leiſure hours, to your Grace; in the hope, that it may ſerve more generally to diffuſe the ſuperior military knowledge of M. D'Antoni.

I beg leave to ſeize this opportunity of expreſſing my wiſh, that the Royal Regiment of Artillery may long

flouriſh under your Grace's protection, and of ſubſcribing myſelf,

MY LORD DUKE,

*Your* GRACE'S *moſt obedient*

*and devoted humble Servant,*

The Tranſlator.

THE

# THE TRANSLATOR'S PREFACE.

LITTLE apology is neceſſary for giving to the public in an Engliſh dreſs, the three following treatiſes, written originally in Italian by M. D'Antoni; who, from his extenſive knowledge and voluminous publications, ranks high among the military writers of the preſent age.

The object immediately propoſed by the author in theſe and his other works, is the inſtruction of the young officers of artillery and engineers; and the ſtudents in the military academies, over which he preſides. From this circumſtance and from the particular ſubject of theſe treatiſes, it may at firſt ſight be conceived, that their ſcope is too confined to merit general attention; but this objection will inſtantly vaniſh

on

on the reflection, that from the various combinations and calculations, which inevitably enter into the military ſyſtems of modern days, a courſe of ſtudy is requiſite to form an officer: and where can this ſo properly commence, as with gun-powder? on the effects of which victory or defeat eſſentially depend. The evolutions of ſquadrons and the manœuvres of battalions are in themſelves neceſſary parts of a military education; they ſtand in the predicament of many other qualities, which it is reproachful to want and not very meritorious to poſſeſs: "Multa "ſunt, quæ quamvis cognita non magnam mere-"antur laudem, eadem tandem ignorata non leve "poſſent dedecus imprimere." But an officer who looks forward to diſtinction will go farther; not content with ſuperficial knowledge, he will trace the military ſcience in its progreſs from the moſt ſimple to the moſt complicated details; examine the properties and force of each particular agent; and thence form thoſe combinations, which adapted to circumſtances and ſituations diſplay, what is juſtly termed, a knowledge of the art of war.

Conſidered in this point of view, there can be little doubt but that the productions of M. D'Antoni may be eminently uſeful: for though many of the obſervations may have occurred

to

to ſome writer or other before him; yet the copiouſneſs, and, in general, the originality of the matter, together with the clearneſs of the arrangement, will, it is conceived, render it more ſatisfactory and fit for general uſe, than any preceding work of the kind.

It muſt indeed be confeſſed, that in this country, the inducement for an officer to make a ſtudy of his profeſſion is not very great; weight of intereſt and length of purſe ſuperſede all neceſſity for knowledge or application: few will ſubmit to the drudgery, requiſite for attaining a maſtery of the profeſſion, ſince ſuch attainment avails nothing, opens no avenue to rank or emolument, no proſpect of advancement: in the law, in the church, in other lines of life, learning and application have ſome effect; in the former particularly, there are daily inſtances of abilities forcing their way through the gloom of friendleſs poverty and ſtarting into the broad ſun-ſhine of rank and riches: in the military line, few ſuch inſtances occur.

This picture, however true, ought not to be diſpleaſing; on the contrary, it will, on reflection prove what every true-born Briton inſiſts on with exultation, that the military is a very ſecondary order in the claſs of ſociety. Every thing

thing in the courſe of time finds its level: had the ſituation of this country rendered its exiſtence inſeparably connected with a numerous army; or had an extenſive frontier, expoſed to the invaſion of powerful neighbours, made a chain of fortreſſes requiſite for its protection; the neceſſity of cultivating the military ſcience would have been felt: conſequence would have attended the officer, conſidered both in his political capacity with reſpect to the ſtate, and in his individual capacity as to his ſuperior endowment, and he would naturally have riſen to the higheſt level in ſociety. But the peculiar felicity of our inſular ſituation, having in a great meaſure ſuperſeded the neceſſity of maintaining theſe armies and fortreſſes, we are fallen by a gradation natural to human nature, into the oppoſite extreme: an extenſive line of ſea-coaſt left totally to the protection of the navy; invaluable depoſits of naval ſtores either wholly uncovered, or expoſed to be deſtroyed by a few hundreds of the enemy; and not a ſingle fortreſs, where the young men deſigned for the army, may ſee the operations of attack and defence, and exemplify the leſſons they may have received at their ſeveral academies or ſchools.

It may be urged that officers cannot be formed in time of peace, that all the theory in the world

world is incompetent to this end: the fallacy of this argument, however ſpecious it may at firſt ſight appear, is eaſily expoſed. During the gloom of the middle ages, when the ſun of ſcience underwent a total eclipſe, and the arts, by which the Grecians and Romans had conquered the world, ſunk with all other ſpecies of knowledge into one common grave; while armies, in the ignorant ſpirit of the feudal ſyſtem, were compoſed of peaſantry drawn together on the emergency, badly armed, and worſe diſciplined; there ſeemed little more requiſite to direct their endeavours for the ſudden and ſhort-lived occaſion, than bravery in the officers. But the neceſſity of ſcience was ſoon felt: before mathematics were applied to the purpoſes of war, before ſyſtems of tactics were formed; there was a certain combination of circumſtances founded on calculation and previous arrangement, which every officer commanding a body of troops found eſſentially neceſſary to enſure ſucceſs.

Since the invention of gun-powder and the introduction of fire-arms, what was formerly the effect of muſcular ſtrength, is now the reſult of ſolid principles, deduced from theory and confirmed by experiment. Hence, war as a ſcience, is grounded on certain immutable axioms;

axioms; a knowledge of which, joined to habits of reflection and an acquaintance with the beſt military writers, will go far towards forming an excellent officer.

Not that experience is to be undervalued, or the merit of thoſe depreciated, who by dint of obſervation have in time acquired a very large ſhare of practical knowledge, to their own honour and the advantage of the ſervice; and it muſt be confeſt, that practice unaided by theory will in many caſes effect more, than theory without practice can do: yet while we admit that experience is our ſureſt guide, it muſt be granted at the ſame time, that to make judicious obſervations and accurate experiments; to draw juſt inferences; not to confound the effects of one cauſe with thoſe of another, and to apply our obſervation and experience to the beſt purpoſes; is not a very ſimple or common thing.

Happily for mankind, wars are neither ſo frequent or of ſufficient duration for an officer to be formed by practice alone: the commentator on Polybius, whoſe voluminous work is fraught with excellent maxims and juſt remarks, aſſerts that "the Coup d'Oil" that talent by which a general ſeizes at once all the advantages preſented by a country and improves them to the utmoſt, may be acquired in time of peace by continually

tinually obſerving the varieties of ground offered to the view, and for this purpoſe particularly recommends the "chaſe." Now if this branch of the military art, which perhaps more than any other is the teſt of genius, can be obtained during peace, how much more muſt the ſubordinate parts be within our reach?

It would exceed the bounds of a preface to purſue this idea and point out the plan of education beſt adopted to our natural and political circumſtances: the diſcuſſion of the queſtion, why this iſland ſo fertile in men of genius in all other branches of ſcience, has produced ſo very few men of firſt rate talents in the military line; and why we have had few or no writers of real, original merit on the ſame ſubject, would be naturally involved in the enquiry? let it therefore be diſmiſſed for the preſent, with a hope that the preceding remarks will not be deemed altogether impertinent in the preface to a didactic work.

The ſelection of the three following treatiſes has been made from the reſt of M. D'Antoni's works, in the deſire of diffuſing the knowledge contained in them among military men in general; but more particularly among the officers of artillery: for it muſt be the wiſh of every man, that a corps ſo eminently uſeful as the royal artillery;

artillery; that has obtained the ſeal of their good conduct in the approbation beſtowed on their ſervices, by the men that Britain has choſen to command her armies for ſeveral wars paſt, ſhould ſtill retain their right to the applauſe of the diſcerning part of their profeſſion and to the gratitude of their country. The ſentiments of an artillery-officer, grounded as he ſhould be in the ſeveral parts of military ſcience, are in every ſervice held in high eſtimation; a flattering diſtinction, the right to which can only be preſerved by ſuperiority of knowledge. In this reſpect, the very high ſtate of improvement that the royal academy at Woolwich has attained, and the numberleſs good regulations that have been made within theſe few years paſt, preſent a moſt pleaſing proſpect.

After the recent publications on artillery by Doctor Hutton, wherein he has by a ſeries of the moſt accurate experiments, eſtabliſhed certain principles and deductions, as abſolute data in gunnery; a tranſlation of the treatiſe on gun-powder might by many be deemed ſuperfluous; particularly, as it militates againſt ſome of the concluſions drawn by the learned profeſſor at Woolwich: but whoever reflects for a moment, on the various opinions that have for a long time prevailed among practitioners,

oners, on the theory of powder and its action on projectiles, will be pleaſed to find the opinions of celebrated men brought forward to public view; that the points on which they agree may be laid down as fixed axioms, and thoſe wherein they differ more fully diſcuſſed. Dr. Hutton, for inſtance, aſſerts that no ſtreſs whatever is to be laid on the wadding of guns, with reſpect to increaſing the force of the charge: D'Antoni affirms the contrary, and in this he is ſupported by Colonel Thompſon, who has favoured the world with ſeveral ingenious papers on gunnery. Truth can only be attained by experiment; and to reaſon from effects to cauſes is the only mode for beings acquainted with nothing but effects: without this, cauſes can only be conjectured at; and the different ideas that have at various times prevailed on the ſubject of artillery, is a convincing proof of the groſs error to which conjecture is liable.

Without entering into the hiſtory of the ſcience, it will ſuffice to obſerve, that before Robins, who was in gunnery what the immortal Newton was in philoſophy, the founder of a new ſyſtem deduced from experiment and nature, the ſervice of artillery was mere matter of chance, founded on no principles, or at

beſt, but erroneous ones. All the nations of Europe have joined in commendation of Mr. Robins, and adopted his axioms: yet much remained to be done; and it was left for the abilities and profound ſcientific knowledge of Dr. Hutton, by proſecuting his diſcoveries on a larger ſcale, to confirm his concluſions.

The military reader will not be diſpleaſed with an account of the productions of M. D'Antoni and a ſhort ſketch of their contents: being compoſed in a language that is not in general technically underſtood in this country, they are leſs known than their merit entitles them to be.

M. D'Antoni's works conſiſt of thirteen volumes in 8vo. the firſt in point of publication was the treatiſe or examination of powder: the author, conſidering fire as the baſis of all experiments upon gun-powder, gives in the firſt part of this treatiſe a definition of it; and then inveſtigates its effects on bodies, pointing out the ſeveral modifications it is liable to: he afterwards proceeds to analyze ſulphur, charcoal and ſaltpetre; the properties of which he conſiders individually and then collectively, as in the manufacture of gun-powder, of which he deſcribes the various ſorts. He then lays down a theory of the inflammation of powder, and

and deduces a number of inferences practically uſeful and in general coinciding with the reſults of experiments made in this country. In the ſecond part, after expatiating upon the difficulty of meaſuring the force of fired gunpowder, even when the utmoſt care and precaution are taken to guard againſt error and irregularity; and thence inferring the impracticability of doing it to an abſolute certainty in military operations, where a thouſand circumſtances concur to baffle the attempt: he aſſerts the abſurdity of laying down any rule as regular and conſtant; ſince the utmoſt that can be obtained is an approximation, ſufficient with a tolerable ſhare of intelligence and accuracy for all common purpoſes. To this end, he firſt conſiders the force of powder in its moſt ſimple, and afterwards in its moſt complex ſtate: then having dwelt on its modifications when fired in guns, he paſſes to an inveſtigation of the initial velocity of projectiles, of the law of their impulſion, and terminates the treatiſe with experiments on the reſiſtance of the air.

Having in the former treatiſe, examined the nature and compoſition of gun-powder, and analyzed it's properties, the author in the ſecond work, entitled a Treatiſe on Fire-arms, applies theſe principles to practice: but in order to

carry method and perſpicuity into every part of his ſubject, he takes up the matter ab initio; and in the firſt place treats of the reſiſtance of fire-arms: in the courſe of which, he examines the hardneſs and tenacity of the metals employed in their conſtruction, giving at the ſame time the method of refining and fuſing them, with remarks on the ſeveral proportions in which they are to be mixed together. Then, having made ſome obſervations on the windage, figure, length, and caſting of braſs guns and mortars, he points out the inconveniences ariſing from what is called "the running at the vent," and concludes with the ſeveral methods of proving and examining new guns. The ſecond part of this work is entitled "On Projectiles;" he explains the duty of an artillery-officer, both on battery and in the field, as far as regards the initial velocity of ſhot, the path of the ſhot's flight, and its effects upon works; and calculates the number of men, that may be killed or wounded in action, both by round or caſe-ſhot fired from guns of different calibres at various poſitions of the enemy. He draws a compariſon between the effects of the howitzers and field pieces, and finiſhes with a chapter on ſhells projected from mortars.

The various properties of powder being thus aſcertained,

aſcertained, and its application to fire-arms fully conſidered; the author as a neceſſary conſequent, treats in the third work, "Of the Ser-"vice of Artillery in the Time of War," beginning with the attack of places; in the courſe of which he developes, the firſt diſpoſitions for laying ſiege to a fortified town, wherein are comprehended the proportion of guns and ſtores for the attack of fortreſſes; the precautions neceſſary to to be taken for enſuring the ſafety of the convoys; the ſituation of the park; the conſtruction of the firſt, ſecond and third batteries; the attack of the countermines and the ſurrender of the place: diſtinguiſhing the ſeveral kinds of ſieges, and giving directions for diſmantling and blowing up the works of a reduced fortreſs. The ſecond part includes the whole ſcience of defence; the author is particularly diffuſe on the ſubject of mining, and lays down rules for the defence of a place conſtructed on a ſyſtem of demolition. The third part treats of the field ſervice of artillery: to convey to artillery officers an adequate idea of this eſſential branch of their profeſſion, he enters into the formation of an army, and the ſyſtem of tactics, and lays down diſpoſitions for the march and encampments of armies, and for parking the artillery: in the next place, he gives the

method of diſpoſing the artillery in the day of action; and its uſe in the defence and attack of field-works, together with the principles of their conſtruction; whether for covering a country or intrenching an army: and concludes with the duties to be performed in cantonments and winter quarters. Although theſe three treatiſes did not immediately follow each other in point of time, yet as they are in a manner connected together and form the ſubject of the following work, it was deemed expedient to claſs them together.

The firſt book of military architecture is prefaced with a general idea of fortification and of the art of war, with a ſuccinct account of the writers on thoſe ſubjects. The ſituations proper for regular fortifications are pointed out, with rules and directions for the conſtruction of the body of the place, and out-works of every denomination.

This firſt book containing as it were, the elements of fortification, which is conſidered under three heads, viz. the ancient, the primitive modern, and the preſent ſyſtem, is followed in natural order by the ſecond volume, comprehending the attack and defence of regular fortifications.

The third comprehends the maxims and principles

principles of fortification; with remarks on the various ſyſtems that have been hitherto publiſhed, and directions for diſpoſing the mines in a regular fortreſs.

The fourth includes the whole ſyſtem of irregular fortification.

The fifth treats of the materials uſed in the conſtruction of works, with directions for aſcertaining their ſeveral qualities; and concludes with a chapter on hydraulics, and on works that are to be occaſionally made in water.

The ſixth comprizes irregular attack and defence, and the ſyſtems of field fortification.

In the two volumes on natural philoſophy and mechanics, ſtiled "Phyſico-mechanical Inſti-" tutions," the author treats of the various branches of thoſe ſciences which he eſteems indiſpenſably neceſſary for an artillery officer to be acquainted with, and enlarges on chemiſtry and metallurgy, which are brought into practice in the analyſis of powder and the treatiſe on fire-arms.

The practice of artillery in time of peace, contains rules for examining and proving guns, ſhot, ſhells and powder; with the dimenſions of pieces of ordnance, and of the carriages uſed in the ſervice of artillery; the conſtruction of the furnaces and moulds for caſting cannon, and

the duties of the laboratory and arſenal are explained.

In the eſſay "On the Management of Guns, &c." are comprehended directions for uſing the ſeveral machines, as the gin, capſtan, &c. and diſpoſitions for poſting the men numerically to the ſeveral duties.

This is a ſlight ſketch of the contents of theſe volumes, which altogether form a complete ſyſtem of artillery and engineering; and perhaps, in a future day, ſome individual whoſe leiſure permits may favour the public with a tranſlation of them: well would the editor of this work deem his labours requited, ſhould his example excite others of the corps to purſue the ſame route; a route, not ſtrewed, 'tis true, with many flowers, nor leading either to the temple of fortune or of fame, yet abounding with objects ſufficient to afford matter of obſervation and reflection to a contemplative mind.

It will be a ſource of ſatisfaction to profeſſional men to obſerve, that the ſame ideas and modes of practice prevail among men of genius in different countries. M. D'Antoni, for inſtance, makes frequent applications to chemiſtry, and recommends it in common with other branches of natural philoſophy; a courſe of chemical lectures is eſtabliſhed at Woolwich by the maſter-

maſter-general of the ordnance: Who after this concurring teſtimony can doubt, that chemiſtry enters into the education of the complete officer? A former maſter-general laid a foundation for theoretical and practical knowledge by founding the royal military repoſitory; where the inventions of ingenious men of all nations in the military art may be collected together and diſplayed both in models and books: M. D'Antoni refers his reader frequently to the models in the royal ſchools; as to a place, whence he may draw from actual obſervation the moſt accurate knowledge with reſpect to the conſtruction and mechaniſm of military machines.

The repoſitory in both countries has been equally productive of a further good: in Turin, it has led to the compilation of a kind of manual of artillery in the two books entitled "the "Practice of Artillery and the Eſſay on the "Management of Guns, &c.": with us, we are indebted to the exertions and abilities of Major Congreve for the eſtabliſhment of a plan of exerciſe, and a ſyſtem of practical knowledge.

It would be tedious to dwell on all the points wherein theſe two ſyſtems agree; the artilleriſt who has made himſelf maſter of the principles eſtabliſhed at Woolwich, will on a peruſal of M. D'Antoni's works find them fully confirmed at Turin.

Turin. Similar inſtitutions at the ſame time and at different places prove their own propriety and utility: one man or ſet of men may err; men of liberal minds and comprehenſion of intellect in different countries thinking alike, can hardly think wrong.

It would be a pleaſing theme to a man, who regards with any enthuſiaſm the future proſpects of the corps of artillery, in reſpect to knowledge and emancipation from prejudice, to dwell on the ſeveral uſeful and ſalutary regulations that have within theſe few years paſt been adopted: but, the enumeration which would gratify zeal, would be irkſome to indifference. One inſtitution, indeed, from its general good to the country merits particular attention. If Britain ranks high in the ſcale of nations, ſhe is indebted for that pre-eminence to her maritime force; the ſecond point in that force, is her naval ordnance: the eſtabliſhment, therefore, of the office of inſpector of artillery became a very important conſideration; the number of guns defective in eſſential principles was become a matter of ſerious alarm; the artifices of contractors and the ignorance of founders made it neceſſary, that officers of knowledge and reſpectability ſhould be appointed to the ſuperintendance of that department: the inſtitution took place under

under the direction of Major Bloomfield, and the good effects reſulting from it are too recent to need recapitulation.

There are ſome points in which M. D'Antoni differs widely from the commonly received opinions: in his proportion of ordnance and ſtores for the attack and defence of places, he omits howitzers and includes a large proportion of mortars. It is doubtleſs an object, highly worthy the attention of profeſſional men to inveſtigate, how far mortars can in moſt caſes ſupply the place of howitzers. The abſurd idea of fixing them in their beds at a certain elevation is at length, to the credit of the preſent day, in a fair way of being exploded: the adoption of Captain Lawſon's mode of elevation, which ſeems at once to unite ſtrength and ſimplicity, the two leading features in military mechanics, will go far toward the completion of this object. The field-howitzer, notwithſtanding the apparent fairneſs of M. D'Antoni's compariſon, will ſtill maintain its ground: it is true as he aſſerts, that the moral effects of howitzer-ſhells cannot be calculated; yet, ſuch is the conſtitution of human nature, that though we cannot aſcertain to mathematical preciſion the force of terror, we are nevertheleſs certain that it works wonderful effects

effects on the moſt ſtupid as well as on the moſt enlightened minds. His general condemnation of light, ſhort guns is deduced from the faireſt of all principles: the only true criterion to judge of the efficacy of field artillery, is their relative effects when compared with muſquets; whenever the fire of artillery can only produce an effect a little greater than a few files of muſqueteers can, no man who conſiders impartially the advantages and diſadvantages attending the uſe of each fire-arm will heſitate to declare, that the artillery ſhould be diſuſed. In ſaying this, there is no reaſon to dread that artillery will loſe any of its credit; profeſſional men will ever know how to eſtimate its conſequence; it is only by bringing forward guns, that cannot produce the effect expected from them, that the ſervice of artillery can be brought into diſrepute. The infantry form the ſoul of an army; it is to ſupport and ſtrengthen their diſpoſition, that guns are brought into the field. Each arm has its particular attribute: to the infantry, belong ſolidity and firmneſs; to the cavalry, velocity and weight of charge; and to the artillery, length of range and irreſiſtible force. As well would a ſquadron of cavalry, whoſe utmoſt velocity could not exceed the quick march of infantry, anſwer

the

the purpoſe of cavalry; as a gun, whoſe range with certainty would not much exceed the range of a muſquet, anſwer the purpoſe of artillery. The reveries of ſpeculatiſts, or the crude, ill-digeſted productions of mere practitioners are equally to be rejected. The perfection of artillery is to unite ſolidity with lightneſs, ſimplicity with ſtrength, and to add length of range to certainty of execution: whoever does the moſt toward attaining theſe objects, is beſt intitled to the gratitude of his country.

There are a few terms uſed in the courſe of this tranſlation that may require a ſhort explanation. A *ſyſtem of demolition* implies a ſyſtem of fortification, where the works are connected together by arches thrown over ditches, or in any ſimilar manner; and where the exterior work may be demoliſhed or taken poſſeſſion of by the enemy, and the communication deſtroyed, without the interior work being in the leaſt degree expoſed or weakened. In ſhort, it is an improved mode of making intrenchments in the baſtion and ravelin and behind the curtain: its invention is attributed to *Buſca* of Milan, who wrote in the beginning of the laſt century.

In treating of mines, the word *proviſional* has been

been adopted; ſince thoſe works which the author terms branches of precaution, are not only intended as *liſteners*, but to be alſo occaſionally converted into galleries and chambers: they differ from the permanent works in not being made before the ſiege, whereas the permanent ones are conſtructed previous to it. All foreign words have been as much as poſſible rejected: why our language ſo rich in other reſpects ſhould be ſo poor in military terms, it is difficult to account for; unleſs it be from the abſurd vanity of ſhewing a knowledge of foreign languages. Surely there is ſufficient ſtrength and copiouſneſs in the Engliſh language to expreſs our ideas; nor have we ſhewn any backwardneſs in adoping new terms when neceſſary; yet we ought to be careful of "naturalizing uſeleſs foreigners to the injury of "the natives;" and rather form a word from our own ſtock than admit needleſs circumlocution or foreign idiom. Dr. Johnſon left much to be done with reſpect to technical terms; but it is to be hoped that the Oxford Lexicographer will amply ſupply this deficiency; and not leave the military language a prey to every petty innovator. A ſtandard of terms ſhould be ſettled: this can only be done under the authority of ſome judicious compiler, who may

ſtamp

ſtamp a lawful currency on ſterling words, and proſcribe thoſe that are unneceſſary or improper.

It cannot eſcape the intelligent reader, that M. D'Antoni has adapted his directions for the conduct of officers, to the meridian of his own country: Turin has the Alps on one hand and the plains of Lombardy on the other; the greater part of the wars in which the Piedmonteſe have been engaged, have been in the Alps, the frontier towards France and Savoy; and ſome of their ſtrongeſt fortreſſes are expreſsly for the defence of the paſſes of the mountains: this will account for the frequent introduction of remarks on mountainous ſituations.

A compariſon between the Engliſh and Sardinian artillery will prove that there are many points wherein our ſervice is better arranged, and many inſtances where we have the advantage of them in reſpect to mechaniſm and the making up of ſtores: but this will detract nothing from the goodneſs of the general principles, nor invalidate in the ſmalleſt degree the juſtneſs of the author's obſervations. The difference of the two ſervices in one reſpect is particularly ſtriking: with us, the engineers are accuſtomed to conſtruct the batteries, the artillery officer having little more to do than prepare

prepare the ſtores and fight the guns: in the Sardinian, and indeed, in moſt other ſervices on the continent, the artillery officer plans the batteries in conjunction with the engineer, and conſtructs them himſelf: how far this method may be advantageous, it would be foreign to the preſent purpoſe to diſcuſs. Should it appear that M. D'Antoni brings the artillery officer too much to the fore ground of the picture, it ought to be recollected, that he profeſſes to regard artillery only, as one of the principal conditions in the conſtitution of an army; and perhaps ſome little allowance may be made for predilection to a favorite ſervice.

The tranſlator had at one time an intention of ſubjoining by way of note, remarks on the ſeveral concluſions drawn by the author in the courſe of this work; and comparing them with the received opinions of the Engliſh and French artilleriſts, and with the diſcoveries and improvements made in the ſeveral branches of ſcience on which he treats: but beſide, that an ample diſcuſſion of theſe ſeveral points would have ſwelled into a voluminous commentary, it might have involved him in controverſies in which neither his time nor his inclination permitted him to engage.

A ſecond plan was merely to give ſuch remarks

marks as neceſſarily grew out of the ſubject: but this was abandoned, as imperfect; and the reader is left entirely to the ſuggeſtions of his own mind, with reſpect to the merits or demerits of the work. The tranſlator has only taken advantage of the different genius of the language, to condenſe as much as poſſible, what he conceived to be, the meaning of the original; and has left the mathematical and algebraical parts exactly as they ſtood, with the ſimple alteration of the weights and meaſures. To have ſhewn by notes, as was intended, the conſtruction of the theorems would have been an operation of great length; the mathematical reader is therefore referred to the Phyſico Mechanical Inſtitutions. All the weights and meaſures are reduced to the Engliſh ſtandard: this, though a work of much labour, was deemed neceſſary; and indeed without it, a tranſlation would be very defective. The ſame denomination is left to the guns to diſtinguiſh their ſeveral natures, as in the original; it being found that they correſponded to natures unuſed among us and to fractional parts: it was therefore apprehended that the moſt ſimple mode was to leave them as they were; the reader having only to recollect that the 32 pr. correſponds to the 27 pr. Engliſh; the 16 pr.

to $13\frac{1}{2}$; the 8 pr. to $6\frac{3}{4}$; and the 4 pr. to $3\frac{3}{8}$. One alteration indeed was judged neceſſary in ſpeaking of guns: they are divided by M. D'Antoni into two kinds; viz. heavy and light: but the term light when applied to guns of that length and weight appeared ſo inapplicable to our idea of light guns, that the tranſlator has taken the liberty of uſing the term *medium* guns, being an expreſſion familiar to an Engliſh artilleriſt: reſerving the term light for thoſe ſhort, light guns which M. D'Antoni propoſes for ſallies, &c.

Some difficulty occurred in fixing the preciſe proportion between the Piedmonteſe and Engliſh weights and meaſures. The Piedmonteſe artilleriſts uſe the Lyprand foot: now the length of the ſecond-pendulum at Turin being $\frac{3}{10}$ of this foot, and at London $39\frac{2}{10}$ Engliſh inches; the foot Lyprand of 12 inches, making a very ſmall allowance for the difference of latitude, is equal to 20.23457 Engliſh inches. The accuracy of this proportion is confirmed by the ratio between the diameters of the Piedmonteſe and French ſhot, as laid down by M. D'Antoni. The French 24 pr. ſhot is equal, he ſays, in diameter to the Piedmonteſe 32 pr. and the French 24 pr. being known to be equal to the Engliſh 27 pr. the former proportion anſwers

anſwers very exactly for the diameters of the ſhot. Having thus eſtabliſhed the relative diameters of the ſhot, it was eaſy to determine their weight; and thence, the proportion between the Piedmonteſe and Engliſh pounds; which is as 1·00 : ·82, or the Piedmonteſe pound is 13oz. 2 dr. Engliſh. It is true, that this differs from the common ratio eſtabliſhed in the tables of the weights of the ſeveral nations of Europe, but agrees with Ferguſon's table inſerted in his tracts; wherefore we may conclude that in Piedmont, as in moſt other countries, there are two weights. The relative numbers in the tables in the ſecond treatiſe are unaltered, as they would ſtill have borne the ſame proportion to each other; but the ranges and lines of deſcent are expreſſed in Engliſh meaſure.

In fine, the tranſlator truſts that this work will prove an uſeful addition to the ſoldiers library: with regard to the merit of the original, he can only ſay in ſupport of his own judgment, that it has been deemed worthy of tranſlation into the French language by officers of high rank. The Treatiſe on Powder was tranſlated by M. le Viſcomte de Flavigny: the Treatiſe on Fire-arms, by M. le Marquis de St. Auban, lieutenant general in

the French ſervice; who thought the evening of a life, during which he had made 17 campaigns, had been preſent at 38 battles or ſieges, and had ſerved 46 years, well and uſefully employed in giving to the officers of artillery, in which corps he had acquired great reputation, a work that he deemed excellent: the third treatiſe was tranſlated by M. le Chevalier de Mont-Rozard, lieutenant colonel of artillery, an officer of great merit and experience. Theſe concurring teſtimonies, joined to the opinions of ſome officers in our ſervice of great profeſſional knowledge, induced the tranſlator to offer the following work to the public. He was well aware, that in the performance, two duties would neceſſarily be exacted from him; the one he owed to the author, the ſecond to the public: by the former, he was bound to give the ſenſe of the original with fidelity and accuracy; by the latter with perſpicuity and conciſeneſs. How far theſe objects may have been fulfilled, is left to the public to decide: to that tribunal he ſubmits in the confidence, that if his abilities have by any means been equal to his zeal, the verdict muſt be in his favour.

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TREATISE

# TREATISE ON GUN-POWDER.

## FIRST PART.

### OF THE PROPERTIES OF GUN-POWDER.

*The properties and effects of Gun-powder can only be aſcertained by the means of Fire: let us, therefore, in the firſt place, examine the nature of Fire itſelf; according to the doctrine of thoſe philoſophers, who, by the cloſeſt inveſtigation of its effects, have endeavoured to explore its principles and cauſes.*

### CHAP. I.

### OF FIRE.

THE celebrated HERMAN BOERHAAVE, whoſe opinions have been adopted by the moſt eminent chemiſts, could only, after a long ſeries of experiments, diſcover a few of the properties from which fire has derived its ſeveral denominations; according to the various modifications under which it preſents itſelf to our ſenſes.

1. Pure fire is called *fire*, *ſolar matter*, *light* and *heat*: under this idea it is conceived to be a ſubſtance eſſentially fluid, compoſed of particles very ſubtle, and continually agi-

tated, though not always in the ſame degree. The learned BECCARI has proved that it exiſts in all places, and in almoſt all bodies, without being able to decide whether it be a conſtituent and eſſential principle. A gentle friction of a globe of glaſs in the electric machine, ſhews that every thing partakes of it; and two hard bodies rubbed violently together gradually grow warm, and at length emit ſparks and flame according to their ſeveral qualities.

2. Fire, which ſeems to paſs from a fluid to a ſolid ſtate, and become a part of the body, as the inflammation of ſome bodies evidently ſhews, is called *combuſtible matter, ſulphur, the food of fire*, and *phlogiſton*.

3. One of the diſtinct characters of fire, conſidered as ſolar matter, light, &c. (1.) is to eaſily penetrate bodies, by inſinuating itſelf into them equally, and expanding them ſo as to cauſe a disjunction of the component parts when introduced in quantity. But the facility with which fire effects this is different, according to the qualities of the bodies it enters: there are even ſome which, far from being dilated by the action of fire, are contracted; as wood, animal bodies, &c.

4. Another character of fire is, to render ſubſtances luminous, either by means of the flame which breaks from them, or by their becoming red.

5. Fire, conſidered as combuſtible matter, ſulphur, phlogiſton, &c. (2.) cauſes no change in the body in which it reſides, nor does it communicate to it either light or heat, unleſs it paſs from a quieſcent ſtate to ignited motion, or inflammation.

6. The different effects of the firſt ſpecies of fire may be conſidered under three heads.

1. In a determined ſpace.
2. As actually exiſting in a body.
3. With regard to the manner and law in which it enters and expands bodies of different natures.

7. Conſidering fire in a determined ſpace, we find that, as its quantity and velocity may vary, ſo alſo in the ſame proportion will its activity and efficacy be different; as may be obſerved in burning glaſſes, reflecting teleſcopes, &c. The activity and efficacy of fire can only be aſcertained by the expanſion of bodies, and the disjunction of their parts; but hitherto the method of meaſuring exactly not only the quantity

quantity and velocity of fire ſeparately, but even its abſolute effects on bodies, are unknown. The point to which a body entirely deprived of fire can be condenſed is equally undetermined with the firſt inſtant of its expanſion. The condenſation of mercury, produced by a certain quantity of ſal ammoniac and ſnow mixed together, is, in the conſtruction of thermometers, the loweſt point that we know; while that, from experiments made in more northern climates, it is clear that mercury can be much more condenſed. In the conſtruction of pyrometers, the point of the greateſt condenſation depends on the variable temperature of the atmoſphere. Thus theſe two inſtruments ſerve only to ſhew, by their graduation, the difference of expanſion, according to the degree of fire that they contain or are penetrated with.

8. The activity of fire conſidered as actually exiſting in a body, (6. N° 2.) depends not only on the quantity and velocity of the ignited matter, but alſo on the maſs of the body in which it exiſts. On attempting to reduce two fluids of unequal denſity to the ſame temperature, the moſt denſe requires the greateſt degree of heat: thus, when the activity and degree of fire which the two bodies contain are proportional to their reſpective maſſes, they are equally hot. On touching two bodies of unequal denſity, reduced to the ſame temperature, the moſt denſe appears the hotteſt; becauſe the hand being in contact with a greater number of particles in the denſer body, the ſenſation excited is proportionally ſtronger.

9. The manner and law (6. N°3.) under which fire penetrates bodies, is modified by the degree of its activity, the time of application, and the ſuperficies, quality, and maſs, of the ſurrounding bodies; for ſhould any one of theſe circumſtances vary, a different modification will reſult. Put into the ſame fire two pieces of iron of the ſame quality, but of different ſizes, the ſmaller piece will become hot much ſooner than the larger one; and if the ſurface of the larger piece be increaſed by flattening it with a hammer, it will become hot in leſs time. This diverſity of effects may be equally remarked on comparing a piece of iron with a ſtone, or any other body, put into the ſame fire.

Theſe obſervations on the facility with which fire inſinuates itſelf into bodies, are equally applicable to the facility

with which it quits them, and diverges from its focus: for when the quantity of fire in any body is greater than in the atmoſphere or other ſurrounding bodies, it quits that body, and removes from it, ſpreading itſelf equally on all ſides; its activity diminiſhes in proportion to its diſtance from the body which it quitted, and its extenſion depends on its exceſs over the external fire, on the time of application, the ſuperficies, quality, and maſs, of the ſurrounding bodies.

10. Having thus examined the various circumſtances that tend to modify the effects of fire, let us now conſider theſe modifications with reſpect to the ignition and deſtruction of combuſtible bodies. Whether the ignited motion excited in a combuſtible body appears under the form of flame, or burning coal, it is always produced in two manners; *either by applying to the combuſtible body a quantity of external fire*, or *by increaſing the motion of the fire that exiſts in it.*

11. From the facility with which combuſtible bodies take fire, they may be ranged in two claſſes. In the firſt may be placed ſpirits of wine rectified, ſulphur, &c. in which, by applying fire to any one part, it is communicated to the whole maſs, ſo as to produce a total deſtruction. In the ſecond claſs may be ranked coal, the greater part of vegetables, &c. in which fire can be propagated only by a continued application; by increaſing the motion in the ignited parts; or by placing the bodies in ſuch a manner, that the fire, in eſcaping from the burning particles, may meet almoſt inſtantaneouſly thoſe not yet ignited.

12. The degree of ignition varies according to the different qualities of the bodies themſelves; for a greater degree of fire is requiſite in proportion to the rarefaction of the ſurrounding air, or to the difficulty of removing from the ignited body ſmoke or other ſubſtances which do not ſerve as food to fire. In both theſe caſes, it is neceſſary either continually to apply freſh fire, or to increaſe the motion of that which already exiſts in the body.

13. From theſe premiſes, it may be inferred, that fire admits of infinite diverſity in its effects, ariſing not only from the time of application, the ſuperficies, quality, and maſs, of the bodies to which it is applied, and which ſurround it, but even from the modifications that enſue from the quantity and velocity of the ignited matter.

14. Where-

14. Wherefore, the force of gun-powder fired in muſquets, cannon, mortars, mines, &c. being in proportion to its inflammation, its effects muſt inevitably be modified by the quantity and the proportion of the ingredients, the temperature of the atmoſphere, and other circumſtances that will be hereafter pointed out. And ſince it is not in our power to determine every point that affects its inflammation and total conſumption, we cannot be always certain of producing the ſame effects with the ſame quantity of powder fired from the ſame piece of ordnance.

## CHAP. II.

### OF SULPHUR, SALTPETRE, AND CHARCOAL.

15. SULPHUR is a ſubſtance compoſed of *vitriolic acid and a combuſtible matter.* It is ranked in the claſs of minerals, becauſe it is extracted from the bowels of the earth. When expoſed to a moderate degree of heat, it liquefies, and ſublimes in little tufts called *flowers of ſulphur:* thus it is purified from heterogeneous ſubſtances by ſublimation.

16. The property of ſulphur is to take fire, inflame, and be entirely conſumed, when expoſed in the open air to a ſtronger fire than that which will liquefy it. It is made uſe of in the compoſition of gun-powder, becauſe the ignited motion is eaſily propagated in it.

17. The facility with which ſulphur takes fire and burns depends on the rarefaction of the ſurrounding air. To burn it in an exhauſted receiver, it requires a continued application of a much greater degree of heat than would inflame it in the open air: the receiver ſhould alſo be of a ſize proportioned to the quantity of ſulphur, leſt the condenſation of the ſmoke prevent its total conſumption. (12.) The only method of decompoſing ſulphur is by burning; which deſtroys the combuſtible matter, and the vitriolic acid exhales in vapour.

18. Charcoal, uſed in the compoſition of gun-powder, is defined to be a body compoſed of *a combuſtible matter, and*

*of the denſe earthy particles contained in vegetables.* In making charcoal, the vegetables are burned in ſuch a manner, that they do not inflame; and then the combuſtible matter unites itſelf intimately with the moſt denſe earthy particles. Charcoal can only be decompoſed by fire; which, at the beginning of the ignition, ſeparates the combuſtible matter from the earthy particles; which are then termed *cinders.*

19. When charcoal is expoſed in the open air to a ſufficient degree of fire, its property is to burn and be conſumed. It ſometimes emits a little blue flame; but more frequently ſparkles, and becomes red, without emitting any flame. If, in this ſtate, it be agitated by the wind, it appears of a more lively and brilliant red in proportion to the force of the wind, and is ſooner reduced to cinders. From this property it enters into the compoſition of gunpowder.

20. Generally ſpeaking, charcoal appears red only when a greater degree of fire is applied to it than will burn ſulphur: the propagation of the ignited motion, and its total conſumption, are effected more ſlowly than in ſulphur. Theſe effects differ according to the quality of the charcoal: that which is the lighteſt, or which contains leaſt of the denſe earthy particles, takes fire and is conſumed the quickeſt.

21. The more the air is rarefied, (12.) the more difficultly charcoal burns, and the greater degree of fire is requiſite to keep it red-hot.

22. Saltpetre is formed from a combination of *the nitrous acid with a fixed alkali.* It is extracted principally from animal and vegetable ſubſtances, found in a putreſcent ſtate, mixed with ſtones, earths, and plaiſters; and is ſeparated from them by boiling them in a water impregnated with a fixed alkali. The ſalt chryſtalizes in long filaments, lying the one upon the other. This is the only method of purifying it; and muſt be repeated two or three times, according to the quantity of the heterogeneous matters. When, by this proceſs, the ſaltpetre has been well purified, it has always the ſame properties, from whatſoever ſubſtances it may have been extracted.

23. Its properties are, to diſſolve in water, more fully in boiling than in cold water; and to liquefy, by a greater degree of heat than is required to liquefy ſulphur. If the heat be increaſed while the ſaltpetre is in fuſion, it ſublimes

in

in viſible particles; which, collecting together on the upper part of the veſſel, are called *flowers of nitre*. To ſeparate the acid from the alkali, without putting the ſaltpetre in contact with a combuſtible body, it is neceſſary to expoſe it a long time to a very ſtrong fire; and even then the decompoſition is brought about very ſlowly.

24. If a combuſtible body, containing a ſufficient degree of heat, touch ſaltpetre, a very fierce flame is excited at the point of contact, accompanied with detonation and a wind, which increaſes the activity of the fire. In this operation the acid is ſeparated from the alkali, and diſſipated. The combuſtible body is inſtantly conſumed, and the alkaline reſiduum is termed decompoſed or fixed nitre.

25. This decompoſition of ſaltpetre takes place equally in the open air and in vacuo; provided that, in vacuo, the action of the fire be ſufficient to keep the combuſtible body (12.) in a ſtate of ignition.

26. Saltpetre may be decompoſed by fire in two ways.

1. By coming in contact with an ignited combuſtible body when in a ſolid ſtate.

2. Or by communicating, when in fuſion, the ignited motion to a combuſtible body in contact with it.

27. In the firſt caſe, by applying burning charcoal, the decompoſition begins and continues till the ſaltpetre or the charcoal be entirely conſumed. To effect the deſtruction of both at the ſame time, the quantity of charcoal muſt be proportioned to the quantity of ſaltpetre. The better the ſubſtances are mixed together, the more immediate will be the contact between the ſeveral parts, and the ſooner will both be conſumed.

28. Burning ſulphur not being able of itſelf to decompoſe ſaltpetre, charcoal is added to it. Now charcoal of every kind burns when expoſed a ſufficient time to the action of burning ſulphur; yet this takes place ſooner or later in proportion to the denſity of the charcoal, or to the quantity of denſe earthy particles; wherefore, that the fire produced from the ſulphur may be ſufficient to burn all the charcoal, the quantity of each muſt be exactly proportioned, and attention paid, at the ſame time, to the quality of the charcoal.

When this proportion is determined, a quantity of ſaltpetre added, and the three ſubſtances well ground together, in order to render the inflammation more inſtantaneous, even then the effects vary; for if the ſaltpetre be

in too great a quantity, the combuſtible particles being too far ſeparated, the fire applied to one part will not be able to ſpread to the others; or the combuſtible particles, being in too ſmall a quantity, will be conſumed long before the ſaltpetre. If, on the contrary, the ſaltpetre be in too ſmall a quantity, it will be conſumed before the other two ingredients: wherefore, that the deſtruction of the three may begin and end at the ſame time, they muſt be mixed in a juſt proportion. As ſoon as the ſaltpetre begins to be decompoſed, the wind (24.) generated from it, renders the heat of the charcoal more intenſe, increaſes the activity of the fire, and accelerates the total deſtruction of the whole. (7.)

29. This decompoſition of ſaltpetre, by the application of charcoal and ſulphur, is ſimilar to the proceſs that takes place when powder is burned in the open air, or in fire-arms.

30. It requires a greater degree of heat to decompoſe ſaltpetre in the ſecond manner (26. N° 2.) than in the firſt.

FIG. I. To the plate A B of the pneumatic machine, fix a thin thimble C, of beaten braſs, with the convexity downward; put into it a mixture of ſaltpetre, ſulphur, and charcoal; and apply a red-hot iron concave in D, ſo that it may exactly admit the convexity of the thimble: in a ſhort time the mixture will explode, and be entirely conſumed. Put again into the thimble an equal quantity of the ſame mixture, and place above the plate a glaſs receiver, from which pump out ſome of the air, then the red-hot iron being applied as before, the exploſion will not ſo ſoon take place. If the air be entirely exhauſted, the decompoſition of the ſaltpetre will not begin till both it and the ſulphur are liquefied, and fall into ebullition.

31. To burn powder in vacuo, the ſecond method muſt be uſed; for it will not explode before it be reduced to a ſtate of liquefaction, and an ebullition enſues.

32. On decompoſing ſaltpetre in either of theſe methods, if the veſſel be ſuffered to cool, and a ſmall aperture be opened, an air will be inſtantly perceived to ruſh out, with a force proportioned to the quantity of ſaltpetre uſed in the experiment.

experiment. This air proceeds from an elaſtic fluid generated at the decompoſition of the nitre, and is eſſentially different from the ſmoke which, after a little time, fixes upon the inſide of the veſſel, and produces no effect. On the contrary, the elaſtic fluid proves its force and effects after a conſiderable interval of time; whence may be inferred, that it is a *permanent fluid*, and in it conſiſts almoſt the whole force of gunpowder. It may be further obſerved, that this force is always increaſed by heat.

33. When the experiment is made in the firſt method, (26. N° 1.) in a cloſe veſſel, with a quantity of ſulphur and charcoal ſufficient to decompoſe the nitre, if the veſſel be too ſmall, or a conſiderable time be requiſite to effect the decompoſition, on account of the want of ſufficient proximity in the nitrous and combuſtible particles, the redundancy of the ſmoke incloſed in the veſſel will retard the operation, the combuſtible body will loſe its heat, and recourſe muſt be had to the ſecond method of continually applying freſh fire.

34. The following experiment proves that the *permanent elaſtic fluid* proceeds from the ſaltpetre alone. Let a quantity of ſulphur and charcoal be burned in a cloſe veſſel, the veſſel be ſuffered to cool, and a hole be opened, no wind will be perceived to iſſue: from this and other experiments, it is clear that no permanent fluid is produced by burning together theſe two combuſtible bodies. The ſmoke, nevertheleſs, is elaſtic when hot; but ſo ſoon as it is deprived of heat, it not only entirely loſes its elaſticity, but even abſorbs a portion of the common air, and a part of the permanent elaſtic fluid generated from the nitre, whenever this fluid mixes with the ſmoke; as will be ſhewn hereafter.

35. From theſe experiments, and others that might be made on the ſame ſubject, the following properties may be deduced—

1. A certain degree of heat is requiſite to ſet fire to the combuſtible bodies, and decompoſe the nitre.

2. The degree of heat muſt be increaſed in proportion to the rarefaction of the ſurrounding air, or to the denſity of the ſmoke.

3. The decompoſition of the nitre being always progreſſive, the more intimate the mixture, and the juſter the proportion of the combuſtible ingredients, the ſooner will it be effected.

4. In

4. In the decompoſition of ſaltpetre, an elaſtic fluid is generated, which is permanent for a conſiderable ſpace of time.

## CHAP. III.

### Of Gun-powder.

36. GUN-POWDER is compoſed of very light charcoal, ſulphur, and well-refined ſaltpetre. Theſe materials are put into a wooden trough, where they are ground together, to render the contact of the nitrous and combuſtible particles intimate and equal throughout the whole maſs. The mixture is occaſionally ſprinkled with water, to form an amalgam, which is afterwards granulated, and prevent the finer particles of the ſulphur and charcoal from flying off, which would neceſſarily alter the proportion of the compoſition. The powder-makers employ more or leſs time in the operation of grinding, in proportion to the quantity of ſaltpetre. When they conceive that the ingredients are properly mixed together, they form from the paſte thoſe little grains which, being dried, obtain the name of gunpowder.

37. There ſeems to be nothing in the fabric of gunpowder that can alter any of the properties of the conſtituent parts, taken either individually or collectively. (35.) The neceſſity of having a combuſtible body capable of producing the total and inſtantaneous decompoſition of the nitre, makes ſulphur and charcoal requiſite ingredients: ſulphur, becauſe it eaſily takes fire, and propagates the inflammation, though the heat it produces is not ſufficient to decompoſe the nitre: charcoal, becauſe its inflammation, as well as the propagation of fire into all its parts, being ſlower, it acquires, when it becomes red-hot, a ſtronger degree of heat than the ſulphur, and is therefore more capable of producing the entire decompoſition of the nitre. Therefore, from their combination with a proper proportion of nitre, the moſt inſtantaneous exploſion may be expected; but if the quantity of nitre be too great, the fire communicating to the combuſtible particles with ſo much the more difficulty as the exceſs is the greater, may produce no effects.

If to a compoſition of 14 parts of ſaltpetre, 1 of ſulphur, and 1 of charcoal, a burning coal be applied, thoſe parts only

only of the mixture in contact with the coal will burn, the flame not being able to communicate itself to the other parts. If, on the contrary, the nitre be in too small a quantity, on applying fire to one part, the flame which breaks out at its decomposition is too weak to spread itself to the others, owing to the great distance of the nitrous particles: the destruction of the whole, therefore, requires a much longer time; and the quantity of permanent elastic fluid, on which depends the greatest force of the powder, is less; as may be proved by burning a mixture of equal parts of sulphur, charcoal, and saltpetre.

38. That proportion which will most readily produce the destruction of all the composition, and yield the greatest possible quantity of the permanent elastic fluid in a given time, ought to be found out, and will constitute powder of the best quality: it evidently appears, from the above experiments, to lie between the quantities there made use of.

39. In the first years that succeeded to the discovery of gun-powder in EUROPE, the proportion of the constituent parts, and the size of the grains, varied very much; which gave rise to the several denominations it has obtained. At the beginning of this century, these proportions and sizes were almost every where reduced to three; and at present, throughout all Europe, only one kind is used for military purposes.

As it will be shewn in this treatise that the properties of powder are modified by the qualities of the ingredients and the size of the grains, to save repeated descriptions of the different kinds of powder that may come under our investigation, we will subjoin a general account of them, according to the various denominations that they are commonly known by; with this observation, that whatever may be advanced concerning the modifications of one kind of powder is applicable to all others.

40. Powder composed of 5 parts of saltpetre, 1 of charcoal, and 1 of sulphur, and granulated so as to enter with ease into the vents of new musquets, is called *musquet powder*; when the grains are three or four times larger, it is called *cannon powder*. Powder composed of 6 parts of saltpetre, 1 of charcoal, and 1 of sulphur, the grains of which are of the same size as musquet powder, is called *common war powder*; and obtains the name of *fine war powder* when the grains are about half that size. Powder made with the same proportion,

proportion, and with grains of the ſame ſize, as the fine war powder, but with a leſs denſe charcoal, is uſed by ſportſmen in ſhooting game. When compoſed of 7 parts of ſaltpetre, 1 of charcoal, and 1 of ſulphur, and granulated as the fine war powder, it is called *fire-work*, or *rejoicing powder*.

41. We will now proceed to prove, that fired powder preſerves conſtantly the properties remarked in the combination of its ingredients; (35.) modified, nevertheleſs, by the exactneſs of the mixture, the ſize of the grains, and other circumſtances that will be pointed out.

42. All degrees of heat are not ſufficient to fire powder for if it be only ſufficient to inflame ſulphur, the effects before mentioned (28, 35. N° 1.) will reſult, as may be proved by throwing ſeveral grains of powder near hot coals. The burning of the grains contiguous to the coals will be ſo inſtantaneous, as not to be diſtinguiſhable from the inflammation of the ſulphur; but the grains at a little diſtance from the coals will emit, after ſome time, a ſmall, blue, lambent flame, which at length becomes brighter; the intenſeneſs of the fire increaſes, and the gradual deſtruction of the ſaltpetre is clearly diſcernible; ſome of the grains are conſumed, while in others the blue flame diſappears without producing their deſtruction: at length the more diſtant grains become warm, without emitting any flame, or being conſumed. This may be exemplified by putting ſome large grains of powder on an iron plate, which may be put near to, or drawn back from the fire, in order to give it different degrees of heat; or by directing upon them the ſolar rays, united by means of a convex glaſs, as different degrees of heat may be produced by augmenting or diminiſhing the circle formed by the re-union of the rays.

43. Theſe experiments prove that powder, like other combuſtible bodies, may become hot or inflamed, without being in the ſame inſtant conſumed. It is neceſſary, therefore, to diſtinguiſh between the inflammation and the final deſtruction of each grain: for fire, when applied to two grains of different ſizes, does not always cauſe any ſenſible difference in their deſtruction; yet there is a great difference in the force of two equal quantities of powder, made with the ſame proportion of ingredients, of the ſame quality, but differently granulated, as is ſeen on comparing cannon and muſquet powder.

44. The

44. The following experiment will prove that the degree of heat to fire powder ſhould be greater in proportion to the rarefaction of the ſurrounding air, or to the denſity of the ſmoke. (35. N°2.)

PLATE I. FIG. II. To the plate A B of the pneumatic machine, let a thin thimble C of beaten braſs, be joined, with the convexity upwards. Let the iron M exactly fill the concavity D; and a moveable ring, F G, be fitted round the thimble, ſo that on covering the convexity C with powder, part may fall on it. Then if M, made red-hot, be introduced into D, when F C G is covered with powder, in the open air, the powder will inſtantly explode; but if a glaſs receiver be placed upon the plate A B, and in part exhauſted, and the hot iron be applied, the exploſion of the powder on C will not be ſo ſudden as before, and part of that on F G will remain unaffected by the heat, in proportion to the quantity of air left in the receiver. When the air is quite exhauſted, the powder upon the convexity C will liquefy before it takes fire, after having emitted ſeveral ebullitions; then explode at once, and cover with its flame the powder upon F G: this will, nevertheleſs, not liquefy; and a part of it will remain upon the ring and plate, where it has been puſhed by the blaſt.

45. This proves that the powder upon the ring, being in a very rarefied medium, does not burn, though ſurrounded by the flame of the fired powder. In this caſe, the fired powder ſpreading itſelf on all ſides in the receiver, which is much larger than the ſpace occupied by the powder, the grains that remain unfired are only ſurrounded by a part of the flame. If the receiver were filled with powder, the fire incloſed in a ſmaller ſpace would be more intenſe, but the quantity of fired powder would be proportioned to the rarefaction of the atmoſpheric air contained between the grains. (FIG. III.) A B C is a funnel of bronze or iron, of which the part C C is made to ſcrew on to V V of a receiver of beaten copper V X Z, containing about 70 cubic inches. The part D F of the funnel, which is to contain the powder for the experiment, may be diminiſhed at pleaſure, by means of the rings G, of exact calibre, and of different lengths, to be applied to the part F of the ſpace D F. A H I is a canal conical from A to H, and cylindrical from H to

H to I; ſhorter than the funnel A B C by half a diameter D D. The part K L of the iron rod K L M, fits the conical part A H ſo exactly, that no air can paſs: the cylindrical part is a little longer than H I. The capital N N O of braſs, of which the aperture O O is leſs than D D, can be faſtened by the ſpirals N N to B B.

Let the ſpace D F be ſo diminiſhed by the ring G, that the remaining part D P be entirely filled with the powder uſed in the experiment; and let the powder be retained by a hog's bladder tied faſt to the thread of the ſcrew B B. The funnel, thus charged, is ſcrewed into V V of the receiver, placed upon the baſe X Z, which keeps the funnel perpendicular. Then if the iron rod be made red-hot, and preſſed forcibly into the funnel, the point M coming below the bottom of the funnel I, without touching the bladder, will nevertheleſs ſet fire to the powder, and the bladder will burſt. If this experiment be made with 24 grains of cannon powder, when the receiver is placed ſo that the lower aperture X Z fits a large tub or other veſſel, no unfired grains of powder will be found; but if the receiver be placed upon the plate of the pneumatic machine, and the air be half exhauſted, $\frac{1}{3}$ or $\frac{1}{2}$ of the grains will be found unfired upon the plate after the exploſion; and if the receiver be exhauſted, $\frac{4}{5}$ or $\frac{5}{6}$ of the grains will be found untouched by the fire.

In theſe three modifications of the air in the receiver, the funnel is always charged in the ſame manner, and with the ſame quantity of powder; and the bladder tied faſt in B B entirely prevents any communication between the receiver and the part D P of the funnel; ſo that when the receiver is exhauſted, no change takes place in the part of the funnel that communicates with the external air by means of the little canal A H I; and conſequently, when the rod is introduced into the canal, the powder incloſed in the funnel, and the air contained between the grains, remain in the ſame ſtate, whatever alteration be made in the air of the receiver; wherefore, the bladder burſting at the beginning of the inflammation of the powder, the air which is between the grains in D P, ſpreads itſelf into the receiver; and in proportion as it becomes more rarefied, leſs powder is fired. In each of theſe three different ſtates of the air in the receiver, it may be obſerved, that the inſides D P of the funnel

nel are bronzed by the flame of the powder. As the powder firſt takes fire in R, that which is placed above in P cannot fall upon the plate without paſſing acroſs the flame of the burning powder in R; ſo that, in this experiment, the fire being incloſed in a ſmaller ſpace, is more active than in the former one; (44.) yet all the powder is not fired, becauſe the air, on the bladder's burſting, is too rarefied.

46. But to deſtroy all doubt of this property of gun-powder, let the funnel be charged as before, the capital N O ſcrewed on to B B, and a wad put at the aperture O to retain the powder: then, if the bladder be tied faſt in q q, and the receiver be exhauſted, the quantity of fired powder will always be greater in proportion as the hole O is narrower; and if it be nearly of the ſame ſize as the hole I of the little canal A H I, all the powder in D P will be conſumed. In the preceding experiment, (45.) it was found, that when the air had been entirely exhauſted from the receiver, only $\frac{1}{5}$ or $\frac{1}{6}$ of the powder took fire, and that a great part of the flame ſpread itſelf into the receiver when the bladder burſt; while that the remaining part expanded itſelf in D P, which it bronzed. On the contrary, in this experiment, where the aperture O O is narrower than D D, as neither the air contained between the grains, nor the flame, is able to paſs with the ſame facility into the receiver, they remain in much greater quantity in D P; the fire is therefore more intenſe, and conſequently a greater quantity of powder is conſumed; indeed all the powder will be fired when O O is reduced to the ſize of I. The ſame effects take place with all kinds of powder, (40.) the only difference being in the quantity that remains unfired.

47. It is then aſcertained (44, 45, 46.) that, in order to fire powder, the heat ſhould be in proportion to the rarefaction of the ſurrounding air, and that it is increaſed by preventing the expanſion of the flame. It remains now to be proved, that the degree of heat muſt be likewiſe greater in proportion to the denſity of the ſmoke.

It has fallen within the obſervation of every artilleriſt, that when ſhells ſink into ſtiff earth with the fuſes downward, the ſmoke finding no paſſage, the fire is extinguiſhed, and the ſhell does not burſt; but if they fall into water, the ſmoke mixing with the water, the fire continues till the powder in the ſhell explodes. Fuſes are generally filled with a

mixture

mixture of mealed powder, ſulphur, and ſaltpetre. Let two or three fuſes, of the ſame ſize, be filled with compoſition of different degrees of ſtrength; after being ſet on fire, let them be buried in earth equally ſtiff, or covered in any other manner, ſo as to prevent the eſcape of the ſmoke; it will be found, on taking them out after ſome minutes, that the quantity of compoſition which is conſumed is in proportion to its ſtrength; ſince the denſity of the ſmoke was the ſame, as the ground was equally ſolid. Hence, it is evident, that the greater the force of the fire, the greater is the conſumption of the compoſition. Care ſhould be taken not to make it ſo ſtrong as to burſt the fuſes.

48. Having aſcertained thoſe two properties, it remains to demonſtrate, that when fire is applied to grains of powder, the inflammation of the contiguous grains, and the deſtruction of each individual grain, takes place progreſſively; (35. N° 3.) and that the velocity with which fire ſpreads itſelf on all ſides to inflame the contiguous grains, is greater than that with which it penetrates into the ſubſtance of each grain. It is too obvious to need inſiſting on, that all motion, however rapid or ſhort it may be, takes up a certain time; though to us, from the ſhortneſs of its duration, it appears inſtantaneous: conſequently, the inflammation and entire deſtruction of powder produced by the action of fire, communicating itſelf to every thing around, like rays from a centre, muſt neceſſarily take place in a determined ſpace of time; which varies according to the ſtrength of the fire, the proportion of the ingredients, the nicety of the mixture, and the ſize of the grains.

When a ſufficient degree of fire is applied to one grain of powder, it firſt acts upon the ſurface, and then penetrates towards the centre. (43.) As the ſurface burns, a flame is excited, which catches the neareſt grains; if the degree of heat be ſufficient, and the ſurrounding air not too much rarefied. In the mean time, the fire which attacked the firſt grain, continues its action towards the centre till it be totally conſumed. There are then two diſtinct actions in the inflammation and the total conſumption of powder: the firſt is the expanſion of the inflamed fluid; which, ſpreading itſelf from the ſurface of the burning grains, ſurrounds the contiguous ones: the ſecond is the penetration of the fire from the ſurface of each grain towards its centre. But the flame always ſpreads with more rapidity between the intervals of the other

other grains, than it penetrates towards the centre of each grain.

49. The following obſervation will prove that a determined time is requiſite for the conſumption of each grain. Make, of the common mixture, ſome grains of powder as large as piſtol bullets; dry, and ſet fire to them: it will then be ſeen that the fire penetrates from the ſurface to the centre, in a longer or a ſhorter ſpace of time according to the ſize of the grains; ſo that if there be no difference between theſe large grains and common ones than in ſize, it may be inferred, from analogy, that the ſmalleſt muſt require a certain ſpace of time, however ſhort. It is likewiſe clear, that the flame, in ſpreading itſelf from the burning grains to the contiguous ones, takes up a certain ſpace of time; as may be exemplified by ſetting fire to a train of powder.

50. An experiment will prove, that the action of fire is alſo progreſſive when applied to powder confined in a veſſel; where the burning fluid being more denſe, is alſo more active than when powder is burned in the open air. (FIG. III.) To the funnel charged as before, (45.) let the capital N O be faſtened, with the aperture O of ſuch a ſize, that the receiver being exhauſted, only $\frac{1}{2}$ or $\frac{1}{3}$ of the powder contained in the funnel may take fire. Introduce the red-hot rod, and leave it to cool; then admit by degrees the air into the receiver, and looſen carefully the capital from the funnel. If proper attention has been paid in this proceſs, it will be ſeen—

1. That nothing touches the point M of the rod; as the powder being burnt all around, leaves a cavity nearly ſpherical.

2. That each of the grains which form the ſides of the cavity are burnt a little towards the concave ſide; as may be diſtinguiſhed by the fixed nitre, and the ſmooth ſurface of each grain.

3. That the grains which are between the interior ſurface of the funnel and thoſe which form the ſides of the cavity, are whitened by the flame of the ſulphur, and that the ſides of the funnel are bronzed.

It is then proved, that the fire both ſpreads itſelf between the intervals of the other grains, and penetrates from the ſurface to the centre of each grain progreſſively.

51. But it is not ſufficient to have proved that the burning of each grain, and the inflammation of the contiguous ones, are progreſſive; it is neceſſary further to ſhew, that the

activity with which fire ſpreads itſelf between the interſtices of the grains, is greater than that with which it penetrates from the ſurface toward the centre of each grain. If we conſider that the inflamed fluid, in paſſing between the grains, meets no other reſiſtance than the common air, which is eaſily penetrated, by reaſon of its rarefaction; and that the fire, in inſinuating itſelf from the ſurface toward the centre of the grain, muſt paſs through a ſubſtance much more denſe; it is evident, that the reſiſtance in the ſecond caſe being greater than in the firſt, the fire muſt conſequently be ſlower in its progreſs.

The following experiment will ſerve in proof of this aſſertion. Let a piſtol barrel, with the vent cloſed up, be filled with powder to the muzzle: on applying fire to it, the barrel will inſtantly empty itſelf, with an exploſion. Let it be again filled with powder well compreſſed, ſo that the interſtices between the grains may be as ſmall as poſſible, and form, as it were, a ſolid body; the time that the barrel will take to empty itſelf will be ſenſibly longer than before.

The great velocity with which the inflamed fluid paſſes from the muzzle to the breech of the piſtol barrel, between the interſtices of the grains, is obſervable in the firſt experiment; and, in the ſecond, it is ſeen how much this velocity, from the neceſſity of penetrating the powder itſelf, is retarded.

52. From the three preceding paragraphs, the following principles are deducible.

1. That in burning two equal quantities of powder, made of the ſame compoſition, but differently granulated, as cannon and muſquet powder, the latter will be conſumed in leſs time than the former; becauſe the grains being ſmaller, (40.) preſent to the fire a greater ſuperficies, and produce, at the firſt inſtant, the inflammation of a greater quantity of matter; which is conſumed ſo much the ſooner, as the fire has leſs ſpace to paſs through from the ſurface to the centre of each grain.

2. That this depends not only upon the ſize of the grains, but alſo upon the facility with which the fire paſſes between them. On the other hand, the grains ſhould not be too ſmall; for then the interſtices will be ſo diminiſhed, as to admit the flame to paſs with difficulty; and they will be ſo compact, as to form, as it were, a ſolid body.

53. The

53. The grains of powder are generally of a very irregular form and uneven ſurface; whence ariſe many varieties in the quickneſs of its inflammation and exploſion. To remedy theſe inconveniencies, ſome manufacturers put the powder into a barrel ſuſpended by iron pivots; and having turned it for ſome time, ſeparate, by means of a ſcreen, the duſt from the grains; which are, by this operation, ſufficiently ſmoothed and rounded. On comparing powder made in this manner with powder of an irregular form and uneven ſurface, the latter is found to take fire more quickly, though the proportion of ingredients be preciſely the ſame in both. Nevertheleſs, as the interſtices between the round grains are larger than between grains of an irregular figure, and as upon them the quickneſs of the inflammation greatly depends, the round grains may be ſo ſmall, that the interſtices being equal in both, the fire may be able to ſpread itſelf equally, and conſume the powder with the ſame rapidity; and as powder of an irregular grain takes fire more eaſily than ſmooth-grained powder, a proportional ſize might be fixed on which would cauſe the latter to inflame with greater, or at leaſt equal promptitude.

54. As theſe properties are common to all kinds of powder (40.) that are well made, of proper materials, and equally dried, varieties in their effects can only reſult from the different proportion of the ingredients, the ſize of the grains, their figure, and ſmooth or uneven ſurface. If the ingredients, however good in quality, are not well mixed together, the powder will not ſo readily burn, and the difference of the effects will be very ſenſible.

55. The following experiment will prove, that from fired powder a permanent elaſtic fluid (35. N° 4.) is produced in great quantity, upon which depends its principal force. (FIG. IV.) A B C Z is a hollow cylinder of bronze, with a ſcrew at B C to receive D E F. G G is a key to open or ſhut the communication between the parts of the funnel H H. To the ſpiral F F, fix the air-gun M M, to receive the elaſtic fluid generated in the cavity B P; and ſcrew D E into B C. Put the powder into the cavity; and ſcrew I K L, made of bronze, into A P. L *m* is the vent; *n o* a ſmall moveable plate of iron, to which is faſtened a fuſe *o p*, and joined to the pin K, &c. *q r* is a ſmooth bar of iron, made to ſlide in a groove by the ſpring V *y*, which keeps it in the poſition *t s*, when not forcibly held back; and cloſing the vent, totally prevents the paſſage of the air; ſo that, when

the ſeveral parts are properly adjuſted, and the bar of iron *q r* is in the poſition *t s*, the elaſtic fluid incloſed in the cavity B P, though very much condenſed, cannot eſcape. Q Q are pivots, or trunnions, to ſupport the machine.

In this experiment the machine muſt be placed vertically, that the powder contained in the ſpace B P may reſt on B X; the little funnel H *b* having been previouſly filled with hog's lard, that the powder, when fired, may not act immediately on the key G G, and prevent it from being drawn out. By means of a thread of ſilk, faſtened with two little nails at the hole *m*, the iron *q r* is held back, the fuſe is charged with powder, and the vent L *m* primed. Then I K is ſcrewed into A P, and fire applied at L; which, communicating by *m*, ſets fire to the fuſe in *o*; and burning, at the ſame time, the thread of ſilk, ſets at liberty the iron *q r*; which, preſſed by the ſpring V *y*, ſlides into *s t*, and cloſes the hole *m*. The fuſe burns from *o* to *p*, and ſets fire to the powder in B X: the vent being cloſed in *m*; and, for greater certainty, a little ſcrew introduced into L.

(Fig. V.) When it is judged that the powder in B X is fired, which can only be known by the heat of the cylinder A B C Z, as no motion can be perceived, let a bullet be put into the air-gun, and the machine be pointed againſt a plank, by means of the ſemicircle of iron B B, which can be ſtopped by C in any direction; then giving a half turn to the key G G, that the cavity B P may communicate with the bore of the air-gun, on touching the trigger A the bullet is diſcharged with velocity, and impinges on the plank with the ſame force as would have been produced by a very great condenſation of air.

The cavity B P will contain ten ounces of powder, but with one ounce only, ſixteen or eighteen bullets may be diſcharged ſucceſſively, and at the diſtance of forty paces, each bullet will paſs through a fir plank half of an inch thick. After theſe diſcharges, if the key G G be turned as it was at firſt, the air-gun be unſcrewed, a large bladder faſtened in its place, and the key again turned, the bladder will be filled with an inviſible fluid; which, being cloſe tied up for ſeveral days, will not ſenſibly diminiſh in bulk. In the coldeſt weather it is equally elaſtic; ſo that, conſidered relatively to its elaſticity, it may be compared to the atmoſpheric air. Unſcrewing K I, the inſide B P X will be found covered with ſaline particles; which, collected and examined, form a fixed alkali

alkali that eaſily attracts moiſture, and falls in *deliquium* when expoſed to an air abounding in vapour.

56. Since the fluid generated at the burning of powder preſerves its elaſticity for a long time, it follows, that at the inſtant of exploſion its elaſtic force muſt be the greateſt. In proof of this, let a barometer be fixed to the pneumatic machine; and, having exhauſted the receiver, apply fire to the thimble. (FIG. I.) At the inſtant of exploſion, the mercurial gage deſcends rapidly, then riſes; and, after ſome undulations, ſeems to fix, for a time, below the point where it was before the exploſion. This apparent fixation ſhews that the elaſtic fluid is reduced to the temperature of the air; and the ſinking of the mercury, in the beginning of the experiment, proves that the force of this fluid is much greater at the inſtant of the exploſion than afterwards. If, inſtead of burning the powder in vacuo, it be fired in the open air, the elaſticity of the fluid will be greater during the application of fire than when its effects totally ceaſe.

57. From theſe premiſes (32, 34.) it may be inferred, that the quantity of the permanent fluid is always in proportion to the quantity of nitre contained in the powder, ſince it alone produces the fluid; as ſulphur and charcoal, when burned, produce none. Other experiments might be made to confirm this, by burning different quantities of powder, of the ſame or different qualities, under the receiver of the pneumatic machine; exhauſting the air to the ſame degree in each experiment, and obſerving the apparent fixed point of the mercurial gage: it would then be ſeen that it ſenſibly falls or riſes in proportion to the ſaltpetre contained in the different quantities of powder.

58. Though the penetration of the bullet into the plank, and the apparent fixed point of the mercurial gage, (55, 56, 57.) be the effects of the permanent fluid generated from the ſaltpetre, yet they ought not to be attributed ſolely to that; as the ſmoke and the common air contained in and between the grains of powder, are alſo rarefied by the action of the fire.

59. From all experiments hitherto made upon ſmoke, it is found to be elaſtic while hot; whefefore it is reaſonable to conclude, that the ſmoke produced at the exploſion is one of the cauſes that concur to give it force: but when cold, it not only ceaſes to be elaſtic, but even abſorbs a portion of the permanent fluid. It is impoſſible, at the exploſion, by ſepa-

rating the ſmoke from the elaſtic fluid, to determine the abſolute force of each; yet it may be ſafely inferred, that the greater part of it depends upon the permanent fluid.

60. The common air that is within and between the grains contributes likewiſe, by its expanſion, to the force of the powder when fired. Its abſolute force might be eaſily determined; but is very ſmall, in compariſon of the elaſticity of the permanent fluid generated from powder.

61. Thus, the diminution of the ranges of fire-arms, when heated by frequent diſcharges, or when the air of the atmoſphere is more rarefied, ought not to be attributed to leſs elaſticity in the air, but rather to the ſecond property of powder; where, being fired in a rarer medium, leſs takes fire though the ſame quantity be uſed; and hence the range is ſhortened, as will hereafter be more clearly proved.

62. For the ſame reaſon, the increaſe of force obtained by triturating powder for a long time, and the force which damaged powder reſumes after having undergone a freſh proceſs, proceed not, as ſome think, from the greater quantity of air compreſſed into the ſubſtance of the powder, but ſimply from a more exact mixture of the ingredients, whence they more eaſily and generally take fire.

63. In illuſtration of this remark, it is ſufficient to obſerve, that the beſt manufactured powder is liable to be damaged by exceſſive heat or moiſture. The powder-makers, in drying powder, take care to ſtir it frequently, and ſuffer it to cool before they put it into the barrels; as they pretend that it ferments when very hot: and in fact, if, when much heated, it be cloſed up in a barrel for ſome hours, and afterwards poured gently upon a cloth, a great part of the grains, eſpecially thoſe towards the middle of the barrel, will be caked together; on examining them carefully, it will be found to be owing to the great heat, which having liquefied the ſulphur, it glues the grains together when cold: but this never happens if the powder be allowed to cool before it is put into the barrel. A partial or total liquefaction of the ſulphur is always prejudicial to the inflammation and quick deſtruction of the powder, (27, 28.) as it deſtroys the exact mixture of the ingredients, which can be only recovered by ſubjecting it to a freſh proceſs. If the heat be not ſufficient to liquefy the ſulphur, a large quantity of duſt, conſiſting principally of ſulphur and charcoal, will be found in barrels of powder that have been long manufactured and expoſed to damp. The powder from which this duſt is detached will be

be altered in quality; and while the interior of the grains, from which the ſulphur and charcoal are fallen off, continue in the ſame ſtate they were in when made, the exterior will have loſt the greater part of the ſubſtances neceſſary to facilitate the inflammation. Thus, on applying fire to theſe grains, the ſurface burns ſlowly till the fire penetrates the interior, and meets a ſufficient quantity of ſulphur and charcoal; the powder muſt therefore have become weaker. Now, if the powder, thus reduced in ſtrength, be manufactured again, the grains will become homogeneous both internally and externally; but, owing to the diminution of the quantity of ſulphur and charcoal, they will be altered in quality, ſince the ſaltpetre will be in greater proportion than either of the other two ingredients; ſo that if, before the powder became damp, it was not very ſtrong, it will now have become much ſtronger; but, on the contrary, if it was as ſtrong as poſſible before, and the ingredients (38.) well-proportioned and intimately mixed together, it will in this new operation have loſt part of its ſtrength. Hence it may be inferred, that grinding ſerves only to mix the ingredients together; and that when there is a perfect contact between the nitrous and combuſtible particles, it is uſeleſs any longer to continue the operation.

64. Powder, however well dried and fabricated it may have been, loſes its ſtrength when allowed to become damp. If daily obſervations on powder, put into damp magazines, and carefully preſerved in barrels, are not ſufficient to eſtabliſh this fact, the following experiment will render it incontestable.

Let a quantity of well-dried powder be nicely weighed, and put into a cloſe room, where the air is temperate, and ſeemingly dry, and be left for three or four hours; on weighing it again, its weight will be increaſed. This ſame powder, expoſed to an air loaded with vapour, acquires much additional weight in a ſhort time. Now the increaſe of the weight being proportional to the quantity of vapour contained in the atmoſphere, and to the length of time that the powder is expoſed to it; it follows, that powder eaſily attracts moiſture.

65. Wherefore, if a degree of heat, ſufficient only to fire dry powder be applied to powder that is damp, the moiſture will oppoſe the action of the fire, and the grains either will not take fire at all, or their inflammation will be ſlower: thus, as the fire will ſpread more ſlowly, fewer grains will

burn; and the penetration of the fire from the ſurface to the centre of each grain, and conſequently their conſumption, will require more time. Whence it may be concluded, that all degrees of moiſture diminiſh the force of powder. Saltpetre, not ſufficiently refined, attracts moiſture very readily; and as the ſubſtances that render it impure leſſen the quantity of fluid, and prevent its detonation, it ſhould be refined as much as poſſible before it is employed in the fabrication of gun-powder.

66. In drying damp powder, the degree of heat ſhould be moderate. (63.) When any of the ſaltpetre has been diſſolved, it ſhould be ground afreſh, to eſtabliſh a juſt mixture of the ſeveral ingredients; and if part of it be abſolutely loſt, which may be known by paſſing a certain quantity of the powder, well dried and weighed, through a ſieve, it will be neceſſary, before it is ground, to add the quantity of ſaltpetre that is deficient.

67. Having thus ſhewn that the force of powder is owing to an elaſtic fluid generated at the exploſion, the ſuddenneſs of which depends upon the proportion of the ingredients, the contact between the nitrous and combuſtible particles, and the ſize of the grains, &c. it may be concluded, that when ſeveral powders, equally well dried, and fired under the ſame ſtate of the atmoſphere, are compared together, that which produces the greateſt quantity of the elaſtic fluid, in a given ſpace of time, is the ſtrongeſt.

## CHAP. IV.

### THE PROPERTIES OF POWDER ARE THE SAME IN FIRE-ARMS OF ALL CALIBRES.

68. HAVING proved that every degree of heat is not capable of firing powder, and that its force depends on the elaſtic fluid generated at the exploſion, it is needleſs to adduce any more arguments in ſupport of this fact; but with regard to the ſecond and third properties (44, 48, 49.) of powder, which are undoubtedly of greater conſequence, and have often, for want of due inveſtigation, occaſioned a difference of opinion among artilleriſts, in treating of the proper charge and length of guns, it is neceſſary to be more particular.

particular. Theſe two properties, as well as the firſt and fourth, hold good in all fire-arms, and in every other cavity where powder is burned; they are alſo modified by the ſame cauſes, (41.) and by others that will be hereafter mentioned.

69. The ſecond property is obſervable in all fire-arms, when, on applying fire to different quantities of the ſame powder, either the whole or a part only of the grains take fire, in proportion to the ſtrength of the fire, and the denſity of the medium. For example, if a quantity of cannon powder be all burned in a gun of large calibre, the ſame quantity, in a piece of ſmaller calibre, will not be all burned. In the ſame piece, charged with different quantities of powder, the ſmaller charge will entirely explode, while a part only of the larger will be conſumed. If, in the largeſt charge, the reſiſtance to the exploſion be increaſed by a high wad, ſhot, &c. a greater quantity of powder will burn than when the piece is fired with a common wad, and without ſhot. Theſe varieties conſtitute the ſecond property of powder. (44, 45, 46, 47.)

70. The third property of powder is equally obſervable in all fire-arms. The inflammation of each grain, and of the contiguous ones, being progreſſive in all kinds of powder, the varieties that occur ariſe not only from the ſize of the grains, and the proportion of the ingredients, but alſo from the ſize of the veſſel in which the powder is fired. For example: if in two veſſels, of unequal ſizes, two equal quantities of powder be burned, the fire in the ſmalleſt veſſel, being moſt intenſe, accelerates the deſtruction of each grain, and all the powder is conſumed in leſs time than in the larger veſſel. The ſame circumſtance occurs, when two equal quantities of powder are burned in veſſels of equal ſize; one of which reſiſts the action of the powder, and the other burſts at the beginning of the exploſion: the heat being more intenſe in the veſſel that reſiſts than in the other, the deſtruction of each grain is accelerated.

71. To prove that the inflammation of powder in fire-arms of all calibres depends on the denſity of the air contained between the grains, and the degree of fire that ſurrounds them, (69.) let a muſquet or piſtol barrel be filled with powder to four or five diameters; let a ſmall wad, made of a ſubſtance not eaſily combuſtible, be lightly compreſſed upon the powder; and let the piece be fired into a veſſel made

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on purpoſe to receive the diſcharge: a certain number of grains will be found unfired; let theſe be collected and weighed. If this experiment be repeated ſeveral times, with the ſame piece, and with the ſame quantity of powder of the ſame quality, and the piece be ſuffered to cool after each diſcharge, the number of unfired grains will be always nearly the ſame. Inſtead of repeating the experiments with the ſame piece, let two or three, of the ſame calibre, but the lengths of which are in the ratio of 1, 2, 4, be charged with the ſame quantity and quality of powder, and fired as above, the ſame number of unfired grains will be found in the veſſel; which proves that the additional length does not contribute to the inflammation of a greater number of grains, provided that the experiments be made with dry powder, and in a very dry day. Theſe effects equally take place in muſquets or cannon: for if a thirty-two-pounder be charged with 8lb. 5oz. of powder, carefully collected together in the chamber, and lightly compreſſed with a wad, and the gun be fired horizontally upon hard ſnow or ice, a great quantity of dirt will be found before the muzzle of the gun, but hardly any unfired grains of powder; but if the gun be fired with 25lb. of the ſame powder, a number of unfired grains will be found: again, with 50lb. of powder, the number of unfired grains ſcattered upon the ſnow will be greater. It evidently reſults, from theſe experiments, that in all fire-arms the quantity of powder that burns is limited. It now only remains to be proved, that this proceeds from the intenſity of the fire, and the denſity of the air contained between the grains; and that when theſe cauſes vary, the quantity of powder that is burned in the ſame piece varies alſo, though the charges be equal.

72. When one of the barrels is charged with the ſame quantity of powder, of the ſame quality, if a very high wad be rammed on it, or the reſiſtance to the exploſion conſiderably increaſed by any other method, after the diſcharge, fewer unfired grains will be collected. This not only correſponds with the reſult of former experiments, (46.) ſince the degree of fire is increaſed by the reſiſtance, but ſerves to confirm the progreſſive inflammation of the grains. But it ſhould be remarked, that the increaſe in the quantity of powder that takes fire is not always proportional to the increaſe of the reſiſtance; for, under ſome circumſtances, a ſlight reſiſtance

reſiſtance cauſes a more intenſe fire than a much greater one does in others.

The experiments made with the machine deſcribed in the third figure, prove that a difference in the denſity of the air between the grains produces varieties in the quantity of powder that takes fire; the following ſimple experiment will further confirm it. Let a muſquet be charged with a full quantity of powder, with a ſingle wad, and fired into a large veſſel, when the air of the atmoſphere is very denſe and dry; let it be again charged preciſely in the ſame manner, and fired when the air is rarefied, as it is ſometimes in ſummer, at two or three o'clock in the afternoon; and, to render the effects more ſtriking, let the barrel be heated by expoſure to the ſun. If the powder, after each diſcharge, be collected and weighed, a much greater number of unfired grains will be found after the ſecond than after the firſt: now the only difference between them being in the denſity of the air contained between the grains, it is evident that this muſt be the ſole cauſe of the varieties that take place. The decreaſe in ranges, obſerved in very hot weather, or when the guns are much heated by preceding diſcharges, ought not to be attributed to the leſs elaſticity of the air, ſince its action, compared to that of the elaſtic fluid generated from powder, is hardly ſenſible; the true cauſe is the rarefaction of the air, whence leſs powder takes fire.

73. The ſize and poſition of the vent render this property of powder ſubject to other varieties. On firing two piſtols, of the ſame calibre, but the vent of the one larger than that of the other, fewer unfired grains will be found in the veſſel from the former than from the latter. The ſame circumſtance occurs when the vent of the one is ſituated at a greater diſtance from the bottom of the bore than the vent of the other, though they be equal in ſize.

74. The charges that at each elevation produce the longeſt ranges, depend alſo upon this property of powder. It is neceſſary to vary the charges according as the denſity of the air contained between the grains differs, as the elevation is altered, or as the atmoſphere is more or leſs loaded with vapour. Thus it conſtantly happens, that on firing at the ſame time two pieces of the ſame calibre, but of unequal lengths, the vents of which are of the ſame ſize and in the ſame poſition; the charge which in the longeſt piece gives the longeſt range, gives it equally in the ſhorteſt piece; provided

vided that the two longeſt ranges of the two pieces, when compared together, be unequal.

75. In ſeeking the charge that gives the longeſt range, it will be found that by uſing ſmall charges at firſt, and increaſing the quantity of powder by degrees, the ranges will increaſe to a certain point; after which, if the charge be augmented, they will progreſſively diminiſh; though the recoil will ſtill continue in the ratio of the increaſe of the charge. This is a conſequence deducible from the foregoing experiments, and agreeable to the principles of mechanics; ſince the recoil and the range ought to be in the reciprocal ratio of the gun and the ſhot, making allowance for the reſiſtance which theſe bodies meet with. Thus, when all the powder explodes, the recoil and the range ought to be in the above ratio; but when a part only takes fire, the burning powder muſt not only impel the wad and the ſhot, but alſo the unfired grains. Now the ſubſtances impelled towards the muzzle of the gun being in greater quantity, the weight approaches nearer to the weight of the gun, which always remains the ſame, and the range is conſequently diminiſhed.

76. The following experiments will prove the third property of powder in fire-arms of all calibres. (70.) Let a gun of any nature be taken, and, to ſimplify the experiment, be charged with ſuch a quantity of powder as will all explode: on examining the ranges from two equal charges of powder, of the ſame quality, but of differently ſized grains, as cannon and muſquet powder, it will be conſtantly found, *cæteris paribus*, that the range produced from the muſquet powder is much longer than that from the cannon powder. Now as the action of fired powder depends on the elaſtic fluid, the ſhot, in the longeſt range, muſt neceſſarily have been impelled by a greater quantity of this fluid: but it has been demonſtrated, (57.) that from equal charges of cannon and muſquet powder, equal quantities of the elaſtic fluid are generated when they are totally conſumed; wherefore, in this caſe, all the fluid is not generated in the time that the ſhot is moving along the bore of the gun, and conſequently we may conclude that its generation is progreſſive. A comparative trial of all other kinds of powder that have the ſame proportion in their ingredients, and differ only in the ſize of the grains, gives a ſimilar reſult: whence it is clear, that each grain is conſumed progreſſively in pieces of all calibres; and

and that the only variation conſiſts in the length of time from the firſt inſtant of its inflammation till its final conſumption.

77. Some artilleriſts, from the intenſe heat excited in a piece of ordnance at the inſtant of exploſion, particularly with large charges, conceived that all the powder muſt be conſumed before the ſhot begins to be in motion; but it having been already proved (71, 72.) that the quantity of powder that burns is limited, it will ſuffice to ſhew, by a concluſive experiment, that the inflammation and deſtruction of each grain is progreſſive. It is well known that fine war powder is much ſtronger than muſquet powder; and that, on firing equal quantities of theſe powders from the ſame piece, the former will give the longeſt range: but if of the ſame paſte from which the former powder be made, grains four or five times larger than thoſe of the muſquet powder be formed, and the difference of the ranges between this large grained powder and muſquet powder, fired in equal quantities from the ſame gun, be remarked, the ranges from the latter will be found much longer than from the former; conſequently the ſhot muſt have been impelled by a greater quantity of the elaſtic fluid. But the large grained powder, if totally conſumed, ſhould produce the ſame quantitity of fluid as the fine war powder, which was found to produce more of it than an equal quantity of muſquet powder. In this experiment, therefore, all the fluid is not diſengaged from the large grained powder, and the deſtruction of each grain is progreſſive, as the charge is ſo proportioned, that the whole ſhould take fire in the gun.

78. This progreſſive deſtruction of each grain is never totally effected within the bore of the gun, in the charges at preſent in uſe; for, independent of the above obſervations, fire is always ſeen to iſſue in great abundance from the muzzle of the gun, which could never happen if all the powder were conſumed before the ſhot began to move.

79. Upon this third property of powder in ſome meaſure depends the difference of ranges in two guns of unequal length, but of the ſame calibre, charged with equal quantities of powder of the ſame quality. The reaſon why the ſhot from the longeſt piece ranges fartheſt, is not only becauſe it is impelled for a longer time by the fluid, but alſo becauſe a greater quantity is generated during that time. But ſhot from long pieces only range farther when at quitting

ting the gun they are ſtill impelled by the elaſtic fluid; or, in other words, when arrived at the mouth of the piece, their velocity is leſs than that of the fluid itſelf.

80. The action of the elaſtic fluid on the ſhot in moving along the bore of the gun is ſo powerful at the beginning of the movement, that the range from a ſmall charge ſometimes equals, and even exceeds, that from a larger charge, though they both take fire before the ſhot begins to move. This is owing to the ſmall charge occupying a leſs ſpace of the bore; whence the ſhot is longer impelled by the fluid, as it has a longer ſpace to move through in the gun. To elucidate this, let an experiment be made with a gun a diameter and half of its ſhot in length; the ranges, or the penetrations of the ſhot into ſoft earth, will be greater when the charge occupies half, than when it occupies a whole diameter. Thus the decreaſe of range in a piece of ordnance that is overcharged ariſes not only from the greater weight of matter to be impelled by the fired powder, but alſo from the leſs ſpace that the ſhot has to paſs through in the piece, and the leſs impulſion of the elaſtic fluid.

81. From theſe premiſes, it will be eaſy to explain, why, in fire-arms loaded in the common manner, only a certain quantity of powder can take fire.

There are two actions to be diſtinguiſhed in the fluid generated at the burning of powder; of fire, and elaſticity. As the fluid ſeparates, and diſengages itſelf from the burning grains, it carries off with it different inflamed combuſtible particles; the degree of fire is then weakened, as much from its expanſion, as from the extinction of the flame, owing to the deſtruction of theſe combuſtible particles: wherefore the fluid, at a certain diſtance from the burning grains, does not contain heat ſufficient to inflame other grains; but its elaſticity, though weakened by the decreaſe of heat, does not ceaſe to act againſt the ſides of the containing veſſel. Now as the inflammation of powder in fire-arms commences at the vent ſituated at the bottom of the bore, there is generated from the firſt grains an elaſtic fluid, which inſinuates itſelf into the interſtices of the other grains; but the more this fluid expands, and the combuſtible particles mixed with it are deſtroyed, the heat becomes leſs intenſe, and unable to fire the grains more diſtant from the vent: but a freſh fluid is ſucceſſively generating, and inflaming thoſe which the firſt produced fluid had not power to inflame; the quantity of the fluid,

fluid, and the intenſity of the heat, increaſe by degrees, till the wad and ſhot begin to move. From this inſtant of movement the ſpace containing the fire, the fluid, and the unfired grains, enlarges; and though freſh fluid is continually generating, yet, as the fire does not increaſe in proportion as the ſpace which contains it is enlarged by the removal of the wad and ſhot towards the mouth of the gun, the unfired grains will not be inflamed; as, from the rarefaction of the air, the fire is not ſufficiently intenſe. Hence we may conceive why, in moderate charges, properly wadded, the fluid has ſufficient elaſticity to force out the wad and ſhot, and, at the ſame time, heat enough to fire all the grains; and why, in charges that are too large, and wadded in the ſame manner, the heat is not intenſe enough to inflame the grains that are diſtant from the vent, while that its elaſticity is ſufficient to overcome the reſiſtance of the ſhot and wad, and put them both in motion.

82. It may be concluded from the preceding obſervations, that the form of the veſſel in which powder is burned has no influence on the force of the elaſtic fluid. Indeed, as the powder may be more compact in one form of chamber than in another, the fire, in ſpreading itſelf from the vent with more rapidity, may inflame more grains; thus a greater quantity of the fluid may be produced in equal times, but the abſolute force of an equal portion of it will not be increaſed. Mortars with ſpherical chambers give the longeſt ranges; becauſe, of all the different forms, of equal contents, in which chambers can be made, the ſpherical has leaſt ſuperficies, as may be demonſtrated geometrically; all the powder, therefore, is nearer to the vent in this chamber than in any other.

83. As the properties of fired powder are the ſame in fire-arms of all calibres, in proportion to the compactneſs of the charge around the vent, the reſiſtance oppoſed to its exploſion, and the variation in the denſity or moiſture of the atmoſphere; it is evident that, in firing equal quantities of powder of the ſame quality, at different times and places, different effects will reſult. If the ſtate of the air be altered, both with reſpect to denſity and moiſture, the ranges will be ſenſibly ſhorter, as the ſucceſſive inflammation of the grains will be ſlower: this frequently occurs when cannon are fired over the ſea, lakes, or marſhy grounds, from which there is a ſtrong exhalation.

It

It will be ſhewn, in the ſecond part of this treatiſe, that the initial velocity of a muſquet bullet, in a very moiſt day, is to its velocity, with an equal charge, in a dry day, as ſix to ſeven.

84. It might be ſuppoſed, that experiments made at different times and places, with mortars conſtructed with the ſame proportions, and from the ſame model, might be concluſive in proving the comparative goodneſs and force of different powders; but the contrary is the caſe: for, independant of the varieties enſuing from alterations in the ſtate of the atmoſphere, there will inevitably be a difference in the conſtruction of the mortars, in ſpite of the utmoſt precaution of the founder. Theſe differences, or inequalities, though ſcarcely diſcernible, will nevertheleſs greatly affect the range; even if the mortars are fired from the ſame ſpot, in the ſame poſition, and with all other circumſtances as nearly correſponding as poſſible.

85. To aſcertain the goodneſs and force of powder, by proving it with a mortar—

1. Fire ſome rounds with a particular powder, made with the greateſt exactneſs, called *proof powder*; then fire the ſame number of rounds, from the ſame mortar, charged with an equal quantity of the powder to be proved, which ſhould be of the ſame kind as the *proof powder*: if the ranges be equal, the force and goodneſs of the powder is aſcertained. It ſignifies little whether the *proof powder*, provided that it be in good preſervation, has at other times given longer or ſhorter ranges; ſince this comparative trial proves that the two powders are of equal force.

2. Before the proof, the two powders ſhould be expoſed to the ſun for ſome time; (63, 66.) and the proof made on a day when the air is clear and ſerene.

3. To leſſen the varieties that any alteration in the rarefaction of the air might occaſion in the inflammation of the powder, or the reſiſtance of the ſhot, the two powders ſhould be fired as nearly at the ſame time as poſſible, and in ſmall quantities, that the whole charge may take fire: wherefore, if the chamber be cylindrical, as it commonly is in *proof mortars*, and the vent ſituated at the bottom, the charge ought not to exceed one diameter of the chamber; though a larger quantity might take fire, if the powder be of ſufficient ſtrength.

4. The

4. The mortar ſhould be firmly fixed in a heavy bed, that the machine may not be deranged by the exploſion, and laid at 45°; the ſhot ſhould be of equal weights and diameters, with the centre of the figure correſponding with the centre of gravity: without theſe precautions, the reſult of the experiments cannot be depended upon.

In this manner the goodneſs and force of powder may be with more accuracy aſcertained, than by any other method yet invented: for complicated machinery is ſubject to numerous accidents; many of which are avoided by fixing the mortars ſo ſolidly and firmly in their beds, as to form as it were but one ſimple machine.

## CHAP. V.

### OF THE CHARGES THAT GIVE THE LONGEST RANGES.

86. TO aſcertain the charges that give the longeſt ranges, has ever been one of the chief objects of reſearch among artilleriſts; it is to be deduced from the ſecond property of powder, and can only be known by experiments made in particular caſes. Having proved, in the preceding chapter, that the ſecond property of powder has effect in all fire-arms (47, 71), and that the quantity which takes fire is in proportion to the reſiſtance to the exploſion, the denſity of the air contained between the grains (72, 74), the ſize and poſition of the vent, the form of the chamber, and the ſtate of the atmoſphere (82), it is impoſſible to fix invariably the charges for giving the longeſt ranges; the utmoſt that can be done, is to eſtabliſh rules adapted to certain determined circumſtances: and, in order to render them uſeful and concluſive, they ſhould be deduced from experiments made with guns of the ſame calibre with thoſe of which the proper charge is ſought, and the common mode of firing ſhould be obſerved.

87. In theſe experiments two objects are principally to be had in view:

1. To find the charge which, of all others under ſimilar circumſtances, will with powder of the ſame quality produce the longeſt range.

2. To aſcertain the greateſt quantity of the ſame powder that takes fire in the piece, fired preciſely in the ſame circumſtances. This diſtinction muſt be carefully obſerved.

It has been demonſtrated, in ſpeaking of ſhort guns (80), that when the greateſt number of grains take fire, the range is not always the longeſt: Now it is eaſy to extend this demonſtration to pieces of all lengths. To ſuppoſe that the charge is entirely converted into elaſtic fluid before the ſhot begins ſenſibly to move from its place, and that the fluid preſerves conſtantly the ſame degree of heat, is to conſider it as liable to no other modification than expanſion as it paſſes along the bore of the gun, which is proved to be falſe in the experiments related in the Philoſophical Inſtitutions. It is there ſhewn, that the longeſt range is obtained from a charge that occupies about $\frac{10}{17}$ of the length of the bore, and that all other charges give ſhorter or longer ranges according to their deviation from this proportion. Thus the experiments made with the powders deſcribed (40), far from invalidating the former concluſion, on the contrary confirm it; by proving, that in fire-arms overcharged with powder, and the ſhots and wads rammed as uſual, all the grains do not take fire, and that all the elaſtic fluid is not generated before the ſhot iſſues from the mouth of the piece. Whence on comparing two unequal charges of cannon powder, the ſmalleſt of which is entirely conſumed in the piece, while the larger is only conſumed in part; it will be ſeen, that though the longeſt range might be expected from the largeſt charge, as more of it may take fire; yet concluſions entirely oppoſite may be drawn from practice: whether it is, that the unfired powder increaſes the weight of the ſubſtances to be impelled; or whether from the quantity of the charge, the ſpace through which the ſhot ſhould paſs is too much diminiſhed. Since, then, in ſpite of the inflammation of a greater number of grains, theſe large charges do not always give the longeſt ranges, and they uſeleſsly increaſe the conſumption of powder, and ſhatter the carriages; our principal object ſhould be to determine preciſely the charge which, of all others under ſimilar circumſtances, will give the longeſt range in pieces of all calibres.

88. There are three methods of determining experimentally the charge that impels the ſhot with the greateſt force, and of courſe gives the longeſt range.

1. By

1. By finding the initial velocity of the ſhot near the mouth of the piece.

2. By firing againſt a butt penetrable and homogeneous, in which may be meaſured the penetrations of the ſhot.

3. By meaſuring the length of the ranges.

The laſt method is the moſt complex, and gives approximations leaſt exact; as ſeveral circumſtances may concur to impede the motion of the ſhot, and alter it's direction; but, as it is moſt common in practice, we will firſt examine it. The inveſtigation of the others will lead us to the ſolution of ſeveral very important problems.

To find the charge that gives the longeſt range—

1. Fire ſeveral rounds from the ſame piece, under circumſtances as nearly ſimilar as poſſible, with ſhot of the ſame kind, and with wads rammed with the ſame force as is generally employed; in a word, with no other difference than in the quantity of powder.

2. Continue firing till a charge be found, any increaſe or decreaſe of which gives ſhorter, or at leaſt equal ranges.

3. Alter the elevation of the guns, and fire ſeveral rounds in each poſition, till the proper charge be found.

Impreſſed with a neceſſity of adhering to theſe principles, and anxious, at the ſame time, to avoid a prolixity that could add nothing to the exactneſs of the concluſions, the officers of artillery at TURIN, in making the following experiments, laid the gun, at firſt, horizontally, and afterwards, at the higheſt elevation the carriages would admit of.

89. The experiments began the 7th of February, and terminated the 30th of March, 1746. They were generally carried on in moderate weather, and in the afternoon. Several rounds were fired from each piece, with equal charges. The guns were mounted on a part of the fortifications of the city, where the axis of the piece was thirty feet higher than the level of the country where the ſhot fell. In the direction of the range a line was traced, and pickets fixed in the ground at every hundred feet; and, to prevent all poſſibility of miſtake, each picket was numbered. To the right and left of the ranges, men were poſted to mark exactly the ſpot where the ſhot firſt grazed; while the officers made the neceſſary obſervations upon the guns, which moved freely upon a ſolid horizontal platform, twenty feet in length, and ten in breadth. The guns were four, eight, ſixteen, and thirty-two-pounders; and thoſe

which had the bore cylindrical, and the vent ſituated at the bottom, were conſtructed according to the proportions laid down in the Firſt Book of Artillery.

| Nature of Guns. | Length of Bore. | Weight. | | |
|---|---|---|---|---|
| *Pounders.* | *Calibres.* | *Cwt.* | *q.* | *lb.* |
| 4 | 27 | 9 | 1 | 9 |
| 8 | 27 | 18 | 2 | 10 |
| 16 | 23 | 31 | 3 | 26 |
| 32 | 20 | 57 | 2 | 17 |

They were fired on their carriages, and loaded with the ladle: the powder was the common-grained cannon powder; four ſtrokes of the rammer were given to the wad over the powder, and three to that over the ſhot, by the ſame gunner, and as nearly as poſſible with the ſame force. The wads were of twiſted hay, properly gauged; the ſhot were weighed, to ſee that they were exactly equal in weight; and the windage was in the ratio of twenty to twenty-one.

The guns being loaded, and pointed along the range, were fired with the axis always horizontal; which was aſcertained by the pendulum and water-level. After each diſcharge, the length of the recoil was meaſured; the wheels were placed in the ſame poſition, between lines, to prevent the ſlighteſt difference. The coins placed under the breech were marked before the diſcharge; and if moved by the ſhock, the experiment was not conſidered as exact.

Theſe precautions being taken, the ſmalleſt charges were uſed at firſt, and increaſed gradually till the ranges began to diminiſh; three rounds, at leaſt, were fired with each charge. The charge that gave the longeſt range having been aſcertained by repeated firings, the principal object was, during the laſt five days, to remark what alteration might ariſe from any change in the ſtate of the atmoſphere; with this view, the ſame gun was fired each afternoon, with the charges marked in the following table. For example, from the four-pounder three rounds were fired, with each of the charges of 1 lb. 4 oz. 1 lb. 10 oz. 2 lb. 1 oz. of powder: the following day, from the eight-pounder three rounds were fired, with the charges of 2 lb. 7 oz. 3 lb. 5 oz. and 4 lb. 2 oz. of powder. In like manner the ſixteen-pounder was fired on the third, and the thirty-two-pounder on the fourth day. At length, to form a compariſon of the ranges of the different guns, on the fifth day the four and eight-pounders were fired, with charges

equal

equal to half the weight of their ſhot: the charges of the ſixteen and thirty-two pounders were equal to $\frac{1}{3}$ of the weight of their ſhot. The following table will ſhew the reſult of the experiments during the five days.

| Nature of Guns. *Pounders.* | Weight of Powder. *lb. oz.* | Length of Range. *Yards.* | Recoil. *Inches.* |
|---|---|---|---|
| 4 | 1 4 | 478 | 43 |
| | 1 10 | 489 | 62 |
| | 2 1 | 472 | 72 |
| 8 | 2 7 | 512 | 45 |
| | 3 5 | 532 | 64 |
| | 4 2 | 532 | 82 |
| 16 | 3 5 | 505 | 42 |
| | 4 6 | 526 | 55 |
| | 4 15 | 522 | 78 |
| 32 | 6 9 | 485 | 54 |
| | 8 12 | 492 | 71 |
| | 9 13 | 489 | 82 |

90. Theſe experiments having been made with the greateſt accuracy, we may conclude, that in cannon fired under ſimilar circumſtances, the charge of powder which will give the longeſt range, is equal to half of the weight of the ſhot in four and eight pounders, and to $\frac{1}{3}$ of its weight in ſixteen and thirty-two pounders; and moreover draw the following inferences with reſpect to two important effects which conſtantly appear.

1. The recoil always increaſes in proportion to the augmentation of the charge, that the length of the range increaſes to a certain point, and afterwards decreaſes in a much leſs ratio than the recoil increaſes.

2. That the charge which gives the longeſt range in pieces of ſmall calibre, is proportionally larger than in pieces of large calibre.

91. The following experiment will explain the cauſe of the firſt effect (90, No. 1.): Charge any piece of ordnance with the greateſt quantity of powder that will all take fire without a wad; after the diſcharge mark the recoil: uſe again the ſame quantity of powder, with a wad ſtrongly rammed on it; the length of the recoil will be greater than at the firſt diſcharge: fire a third round with the ſame charge

well wadded, with the addition of a ſhot and wad over it; the length of the recoil will be again increaſed. At length, with ſimilar charges and wads, and, inſtead of one, putting two or three ſhot into the gun, the recoil will increaſe in proportion to the number of ſhot, and the range will diminiſh.

92. We may eaſily apply this fact to the experiments of 1746.

It has been proved (71 75), that only a limited quantity of cannon powder takes fire: thus, till the charge be ſo proportioned as to be all fired in the piece, a greater quantity of elaſtic fluid is generated in proportion to the largeneſs of the charge. Now conſidering the gun and its carriage taken together as a conſtant quantity termed C, and the ſubſtances impelled towards the mouth of the gun, viz. the two wads and the ſhot, as P; the length of the range ought to be to the length of the recoil as C : P, without making allowance for friction and the reſiſtance of the air to the motion of the ſhot. But as the ſpace that the ſhot ſhould move through in the piece is diminiſhed in proportion as the charge is increaſed, and the *vis motrix* conſequently acts upon it for a ſhorter time; the decreaſe of impulſion muſt be deducted from the action of the elaſtic fluid generated in greater quantity as the charge is larger: Hence it reſults, that the ranges are proportionally ſhorter than the recoil, though they both increaſe as the charge is augmented.

But if the charge be ſo augmented, that a part I arrives at the mouth of the piece without taking fire, then the ſubſtances to be impelled being in greater quantity, the ſame circumſtance that occurs when ſeveral ſhot are put into the piece will in part occur here. As no more grains will be fired, than if the charge were ſmaller and all ignited, the ſhot will acquire the ſame velocity; but the reaction againſt C increaſing at the ſame time, the recoil will be greater than before. The ſubſtances P + I forced towards the mouth of the piece, preſenting to the exploſion of the elaſtic fluid a greater reſiſtance than P alone, and the number of ignited grains and the quantity of fluid generated during the time that the ſhot is moving along the bore being more conſiderable, the abſolute increaſe of fire acting againſt the gun and carriage muſt alſo augment the recoil; while the range may be ſhorter, equal, or longer, than that produced by a charge that is entirely conſumed in the gun, in the ratio that the increaſe of fluid bears to the ſubſtances P + I, and to the ſpace that the ſhot has

has to move through in the piece. This ſhews clearly, that *the ranges or the initial velocities of ſhot impelled from guns are proportionally leſs than the recoils*, and that if the charge be augmented to a certain point, the ranges will diminiſh, while the recoils will increaſe.

93. Thus, very large charges ſhould never be uſed in the ſervice of artillery, as the ranges from them are ſhorter, or at moſt but equal; and beſide the uſeleſs expenditure of powder, the carriages are ſoon rendered unſerviceable, and the greater part of the ſhot are of no effect.

94. The cauſes of the recoil merit a more particular examination. There are two motions in the breech of a gun, at the inſtant of diſcharge; one up and down, by which it ſinks into the coins, and ſometimes throws them upon the ground, if too obtuſe or improperly placed: this reflected movement of the breech takes place when the center of gravity of the gun is too near to the axis of the trunnions, or when the coins are made of too elaſtic a ſubſtance. The other is an attempt to retire with all the machine in a direction oppoſite to that of the movement of the ſhot, which is termed the recoil.

95. The better to underſtand the cauſe of this double motion; let a reſiſting veſſel, in which powder takes fire, be ſuppoſed to have the vent ſtopped at the beginning of the inflammation, no motion will in this caſe be perceived, becauſe the elaſtic fluid, preſſing equally upon the ſides of the containing veſſel, and all the parts having a mutual attraction, its powers are in equilibrio: the balloon inflated with air is a very ſimple demonſtration of this.

96. But if the elaſtic fluid can eſcape through an aperture made on purpoſe, or through a cleft cauſed by its action on the ſides of the veſſel, it will be impelled in a direction oppoſite to the aperture, with a force proportionate to the denſity and velocity of the fluid. For the elaſtic fluid in eſcaping meets reſiſtance from the external air, and impels it and the veſſel in oppoſite directions; and if the veſſel itſelf be not equal in weight to the action of the fluid, it will be put in motion: ſince the column of air which reſiſts this motion, and tends to preſerve the veſſel in a ſtate of reſt, will not be able to prevent it; (its reſiſtance being proportional to the velocity of bodies moving in it:) the greater the velocity with which the fluid ruſhes out, the greater will be the reſiſtance, and the longer the recoil: a number of experiments

might be adduced in ſupport of this, but the common fky-rocket fully exemplifies it.

97. When fire is introduced into the vent of a gun, the action of the breech againſt the coins is in proportion to the denſity of the elaſtic fluid in the charging cylinder: now as the wad and ſhot cannot move before there be a ſufficient quantity of the fluid generated to overcome their reſiſtance, and force out the column of air from the bore of the gun; if the wad be too ſtrongly rammed, or a part only of the powder take fire, or more than one ſhot be put into the gun, or it be more elevated at one diſcharge than another, the reſiſtance to the fluid being increaſed by one or more of theſe cauſes, a greater quantity muſt be generated before the ſhot and wad will be moved. Before this motion commences, there can be no recoil (95), for the ſhot and wad form, as it were, a part of the gun itſelf: wherefore, if ſo large a quantity of ſubſtances be put into a gun, as totally to prevent, by their reſiſtance, the eſcape of the elaſtic fluid, there will be no other movement in the piece than that of the breech up and down againſt the coins; which might, if neceſſary, be more fully demonſtrated. Moreover, ſince a part of the elaſtic fluid eſcapes through the vent during the time of its generation in the charging cylinder, it is clear, that the action of the breech againſt the coins in the oppoſite direction, muſt commence as ſoon as the powder takes fire, but the recoil will begin ſooner or later according to the reſiſtance oppoſed to the exploſion.

98. Hence, if the movement of the breech up and down has not totally ceaſed before the ſhot quits the gun, it may be thrown above or below the point aimed at. When the wheels are of unequal diameters, or not placed in the intervals of the correſponding lines and nails, or the platform on which the gun moves while the ſhot is paſſing along the bore, is not even and ſolid; in all theſe caſes, the gun will not recoil in the proper direction, and the ſhot will be thrown wide of the mark.

99. The length of the recoil during the time that the ſhot is paſſing along the bore varies according to circumſtances. If the charge, for inſtance, be rammed in the common method, and the gun placed on an even horizontal platform, the elaſtic fluid muſt exert more force to move the charge than to move the gun; as is the caſe in uſing the wad-hook to draw out the charge, the gun being drawn forward before

before the wad is diſplaced. If, on the contrary, part of the platform be raiſed, the ſame force that will draw out the wad will not be ſufficient to draw the gun up the inclined plane. Similar varieties occur in the recoil, when the elevation of the gun is altered, or the wheels turn more freely on the axle-tree.

To give to this queſtion a practical ſolution, with reſpect to charges that all take fire in the gun; let the gun and carriage be conſidered as one body = C, the wads and ſhot = P, the length of the bore from the ſhot to the muzzle = D, the recoil will be $= \frac{PD}{C}$. Let one round be fired with a wad over the powder, and the recoil = A. Let a ſecond be fired with the addition of a ſhot, the recoil = B will be greater than A; and $A : B :: \frac{PD}{C} : \frac{BPD}{AC}$ = the length of the recoil in the time that the ſhot is paſſing along the gun. This experiment having been made with a thirty-two pounder, charged with common powder, and fired horizontally on a horizontal platform $\frac{BPD}{AC} = \frac{1}{2}$ an inch. So that if the platform be very ſolid and even for $\frac{1}{2}$ an inch, at the ſpot on which the wheels and trail of the carriage reſt, the remainder of the platform is only uſeful in facilitating the operations of the artillery-men: indeed, as the value $\frac{BPD}{AC}$ may from circumſtances vary a little, allowance ſhould be made for it.

100. Let the ſecond effect (90. N° 2.), viz. that *the charge which gives the longeſt range in pieces of ſmall calibre, is proportionally greater than the charge which gives the longeſt ranges in pieces of large calibre*, be now conſidered. This effect, which conſtantly appeared in the foregoing experiments, could only proceed from the ſize of the vent being equal in the four guns, and from the wads being rammed with the ſame force. From the former circumſtance, a relatively greater degree of fire is produced in the ſmall guns; and from the force with which the wads are rammed, the powder is more compact, and the charge adhering cloſer to the

the ſides of the gun, the reſiſtance is increaſed, and more grains are fired.

101. In the ſpring of 1750, the officers of artillery being directed to inveſtigate ſome profeſſional points under the orders of the Chevalier FERRERO DI PONSIGLIONE, made ſeveral experiments to find the charge that gives the longeſt range, when the piece is fired at the higheſt elevation the carriage will admit of. The guns were of the ſame calibre and proportions as in 1746, only the ſhot being rather larger, the windage was leſs. They were loaded with the ladle with different charges of common grained cannon powder: three rounds were fired from each gun with the ſame charge; the ſame artillery-men gave five ſtrokes of the rammer to the wad over the powder, and three to that over the ſhot; the guns on their carriages, moving freely upon a horizontal platform were always laid at the ſame elevation, and every precaution was taken to load them equally; and meaſure exactly the length of the ranges, upon a flat piece of ground nearly on the ſame level with the battery.

*Reſult of Experiments made in the Spring of* 1750.

| Nature of Guns. | | | Weight of Powder. | | Length of Range. | | Recoil. |
|---|---|---|---|---|---|---|---|
| *Pounders.* | | *Elevation.* | *lb.* | *oz.* | *Yards.* | | *Inches.* |
| 4 | — | 14° | 2 | 1 | 2375 | — | 52 |
| | | | 2 | 8 | 2219 | — | 60 |
| | | | 2 | 14 | 2422 | — | 70 |
| | | | 3 | 5 | 2526 | — | 76 |
| 8 | — | 11° | 3 | 5 | 2321 | — | 46 |
| | | | 4 | 2 | 2463 | — | 65 |
| | | | 4 | 15 | 2486 | — | 85 |
| | | | 5 | 12 | 2375 | — | 102 |
| | | | 6 | 9 | 2675 | — | 119 |
| 16 | — | 12° | 5 | 12 | 2659 | — | 71 |
| | | | 6 | 9 | 2860 | — | 76 |
| | | | 7 | 3 | 2663 | — | 90 |
| | | | 8 | 3 | 2810 | — | 97 |
| | | | 9 | 0 | 2764 | — | 108 |
| | | | 9 | 13 | 2892 | — | 113 |
| 32 | — | 11½° | 11 | 8 | 3172 | — | 117 |
| | | | 13 | 2 | 3032 | — | 120 |
| | | | 14 | 6 | 2995 | — | 124 |
| | | | 16 | 6 | 3220 | — | 146 |
| | | | 18 | 0 | 3084 | — | 168 |

102. It

102. It reſults from theſe experiments, that the charges that give the longeſt ranges when cannon are fired at the higheſt elevation their carriages will admit of, are greater than thoſe which produce the ſame effect when fired horizontally (89). But the ranges do not increaſe in the regular progreſſion that might be expected. For inſtance, in the ſixteen pounder, the charges of 5lb. 12 oz. and 7 lb. 3 oz. gave ranges nearly equal, while 6 lb. 9 oz. gave one much longer. Theſe irregularities proceed from the different charges not having been fired on the ſame day; the 5lb. 12 oz. were fired the 23d of March, the 6 lb. 9 oz. the day following, and the 7 lb. 3 oz. on the 1ſt of April; if they had been fired on the ſame morning, the modifications in the exploſion of the powder, and the air's reſiſtance to the ſhot, reſulting from the alterations in the ſtate of the atmoſphere, would have been avoided: in the 4th and 5th chapters of the ſecond part, this matter will be more fully diſcuſſed.

On repeating theſe experiments with ſuch precautions as to avoid the modifications ariſing from changes in the ſtate of the atmoſphere, the charges (101) that give the longeſt ranges will be found to be almoſt double of thoſe uſed in 1746; but the increaſe of range is of little importance compared to the increaſe of the recoil, and the greater ſhock ſuſtained by the carriage; theſe large charges ſhould never be uſed for common ſervice.

103. In experiments of this kind, a remarkable inequality between two ranges from equal charges of powder will occaſionally occur, though every precaution be taken to fire them under circumſtances as nearly ſimilar as poſſible. Theſe inequalities were neither ſo frequent nor conſiderable in 1746 as in 1750; but it is impoſſible totally to avoid them, for ſuppoſing the direction of the guns to remain unaltered at the exploſion, yet there are two cauſes which ſeparately or conjointly may render the ranges from equal charges of powder unequal.

1. The ſhot in paſſing through the plane of the gun, may not exactly follow the direction of the bore; or on quitting the gun, it may take a different direction.

104. 2. The powder may not be equally well collected in the piece, ſo that charges though equal in quantity, have not the ſame figure: large charges are more liable to this accident than ſmaller ones, particularly when rammed

rammed with the ſame force. In this caſe the quantity of powder fired in the larger charge, varies in proportion to the diſpoſition of the grains to inflammation; for inſtance, in guns laid above the horizon, more powder ought to take fire, as the reſiſtance to the exploſion is greater. The larger the charges, the more frequent are the inequalities in the ranges independent of the violent concuſſion of the carriages.

105. Wherefore, the two extremes of very large or very ſmall charges ſhould be equally avoided; for the firſt does not compenſate for the uncertainty of their ranges, or the great increaſe of recoil, by the additional velocity and force given to the ſhot: and with very ſmall charges, the leaſt difference in the ſize of the wads or ramming, cauſes a great alteration in the impulſion of the ſhot and ultimately in the range; as is often ſeen in richochet-firing, and in mortars loaded with ſmall quantities of powder.

106. This object of aſcertaining the charges that give the longeſt ranges, has engaged the attention of the French, as well as the Piedmonteſe artilleriſts; and the reſult of their experiments appears to be, that in cannon of large calibre, the charge ought to be about $\frac{1}{3}$ of the weight of the ſhot.

The knights of Malta, on ſeeing the report of the French experiments, were induced to direct Sig. MARANDONE, engineer of the order, in the month of Auguſt, 1747, to repeat them. He ſent to the regiment of artillery at Turin a detail of his practice, and aſked the opinion of the officers on the concluſions to be drawn from it. Having obſerved, that on uſing larger charges than $\frac{1}{3}$ of the weight of the ſhot, the ranges ſtill increaſed proportionally; he did not think it neceſſary to purſue his experiments for finding the charge that would give the longeſt range; and judging that the French powder was weaker than his, he concluded that when cannon of a large calibre are charged with a ſtronger powder than the French uſe, the charge which ought to produce the longeſt range, muſt exceed $\frac{1}{3}$ of the weight of the ſhot: this concluſion is conformable to our theory, and the reſults of our practice.

It is clear then, that the artilleriſts in former days, conſumed a ſuperfluous quantity of powder, in making the charge equal to the weight of the ſhot: it even ſometimes exceeded it, as their powder was much weaker than that now in uſe.

107. The

107. The charges we have laid down as giving the longeſt ranges (89, 102) are under ſimilar circumſtances, the ſame in all guns of the ſame calibre, whatever be their length; ſince the increaſe of length does not generally cauſe the inflammation of a greater number of grains (71) the charge which in one gun will give the longeſt range will give it equally in a ſhorter one of the ſame calibre: very ſhort guns are indeed an exception to this rule; for in them the action of the elaſtic fluid upon the ſhot in two unequal charges that all take fire, is at leaſt equal, or even greater, in the ſmalleſt charge; as the ſhot having a greater length of the bore to paſs through (80) is longer impelled by the elaſtic fluid.

108. It only then remains to aſcertain the beſt charges for ſervice; we ſhould previouſly recollect, that the great utility of fire-arms conſiſts in two points: the firſt and principal one is, to ſtrike the object aimed at; the ſecond is, to ſtrike it with a due degree of force. The firſt is ever indiſpenſable; the ſecond admits of certain modifications: for the greateſt force that fire-arms can produce is not always requiſite; and even when it is (Philoſ. Inſtit.) it is better to diminiſh the charge, and leſſen the effect of the ſhot, than run the hazard of miſſing the object, from the uncertainty of uſing very large charges; this needs no illuſtration. Beſide, braſs guns fired frequently with large charges are in a few days rendered unſerviceable; wherefore the advantages and diſadvantages attending the uſe of them ſhould be fully weighed, as upon the preſervation of the guns may entirely depend the ſucceſs of an enterpriſe.

109. To apply theſe conſiderations to practice, and combine the juſtneſs of the range with the neceſſary force, and with the preſervation of the gun and carriage; the charges of powder for ſixteen and thirty-two pounders, ought never in the attack and defence of places to exceed half of the weight of the ſhot, if the gun be properly proportioned (89) and fired at the diſtances ſet down in the ſecond and third book of Military Architecture, and the Treatiſe of Artillery; this we will call the largeſt ſervice charge, and ſhould only be uſed in caſes of neceſſity: the ſmalleſt ſervice-charge ſhould not be leſs than $\frac{1}{4}$ of the weight of the ſhot, and the medium charge $\frac{1}{5}$ or $\frac{1}{6}$ of its weight.

The charge for eight and four pounders ſhould vary according to circumſtances, from $\frac{1}{3}$ to $\frac{1}{4}$ of the weight of the ſhot: the wads in theſe pieces and in thirty-two and ſixteen pounders,

pounders, ſhould be rammed in proportion to the weight of the charge, in order to produce the proper effect; perhaps too much force cannot be uſed, provided that the grains of powder are not cruſhed and beat ſo cloſe as to prevent the fire from penetrating. The charge for richochet and red-hot firing, is very ſmall in proportion to the calibre; it depends in ſieges on the ſituation of the gun, as the diſtance from the enemies batteries is the only point to be conſidered. The charges for field artillery in general actions, in affairs of poſts, in attack and defence of intrenchments, &c. ſhould be between $\frac{1}{4}$ and $\frac{1}{5}$ of the weight of the ſhot, according to the calibre and weight of the gun.

110. Though our obſervations have been hitherto confined to the proper charges for guns; yet thoſe for mortars may be eaſily aſcertained by knowing the quality of the powder, and the form of the chamber. All the mortars now in uſe, in which the communication between the chamber and the chaſe is narrower than the greateſt diameter of the chamber, as the ſpherical, elliptical, parabolic, and thoſe in form of a pear, always range the fartheſt, when the chambers are filled with the common cannon powder, and the ſhell cloſely confined by well ſifted earth rammed upon it; it is clear in this caſe that the charge cannot be augmented. Beſide the concuſſion is more violent, and the ranges are leſs exact, when the chambers are not filled; therefore, to throw a ſhell to a certain point, the chamber ſhould be filled, and the range regulated by the degree of elevation.

111. We will conclude this chapter by ſhewing experimentally how much the difference in the ſize of the vent affects the force of the ſhot. A muſquet was taken $\frac{8}{10}$ of an inch in diameter, and 33 inches in length of barrel. The axis of the large ſcrew which cloſes the breech, was perforated with a hole $\frac{5}{10}$ of in inch in diameter, with ſpiral ſides to receive a ſmaller ſcrew; one end of the ſmaller ſcrew was armed with a little piece of red hot iron, to ſet fire to the powder in the barrel; to the other end a winch was fixed to ſcrew it up; at the part where the vent is generally placed, a circular hole with ſpiral ſides was drilled $\frac{5}{10}$ of an inch in diameter, to which three ſcrews were ſucceſſively applied; the firſt exactly cloſed the opening, and conſequently forced all the fired powder to paſs through the muzzle. The ſecond had in its axis a hole or vent $\frac{1}{10}$ of an inch in diameter, through which a part of the fluid might eſcape; and the third had a vent of $\frac{8}{10}$

of

of an inch in diameter. The muſquet thus prepared was loaded each time with 10 drachms of fine powder put into cartridges, and with an iron ball $1\frac{1}{2}$ oz. in weight; the wads were rammed down with equal force by the ſame man.

The experiments began by firing the muſquet with the ſcrew that entirely cloſed the vent; it was then fired with the ſcrew $\frac{1}{10}$ inch in diameter; afterwards with that of $\frac{2}{10}$, and at length without any ſcrew. The charges were fired by the hot iron ſcrewed into the breech: the object was a plank placed at 5 feet from the muzzle of the muſquet.

The medium of the penetration of the balls in 24 rounds is as follows:

| | | *Inches.* |
|---|---|---|
| In the diſcharges | with the vent entirely cloſed - - - | 6 |
| | with the vent $\frac{1}{10}$ of an inch in diameter - | 8 |
| | with the vent $\frac{2}{10}$ of an inch in diameter - | $6\frac{5}{7}$ |
| | with the vent $\frac{5}{10}$ of an inch in diameter - | 4 |

It reſults from this experiment, that when there is no vent leſs powder is fired, and that which does take fire burns more ſlowly. If the large vent be left open, and a ſheet of paper ſtretched at 2 feet from it, the paper will be pierced full of holes by the powder forced through the vent at the exploſion. Soldiers firing in line are often pricked in the face by grains of powder driven with force from the muſquets on their left; the common opinion that theſe grains are a part of the priming is erroneous.

# SECOND PART.

## Of the Force of fired Gun-powder.

112. IT was ſhewn in the former part of this work that the principal properties of powder are ſubject to many modifications, even in experiments conducted with the utmoſt care. How much more important and frequent then muſt they be when powder is employed in military operations; where, from the nature of things, there can neither be ſo much attention paid to prevent irregularities, nor ſo much accuracy

accuracy in the conſtruction of the machines. In calculating effects deducible from phyſical cauſes, a preciſe ſolution of the problem can never be obtained; it is always compriſed within limits more or leſs diſtant from the abſolute truth, in proportion to the number of cauſes that conduce to the ſame effect. Conſequently in meaſuring the force of powder fired for military purpoſes, no preciſion can poſſibly be expected; and from the nature and number of adventitious circumſtances, the limits that comprehend the ſolution of the problem muſt neceſſarily vary; ſometimes even a general principle will be only applicable to particular caſes. Beſides, as artilleriſts frequently prefer obſervations drawn from practice to rules deduced from theory, it is neceſſary to divide the problem into diſtinct parts, and conſider each of the conditions ſeparately, in order to combine as much as poſſible theory with practice. In the courſe of this examination we ſhall prove, that this combination is in all caſes advantageous, in ſome indiſpenſable.

Theſe preliminary remarks lead to the ſubject of the chapter. Since the inflammation of the grains, and the total deſtruction of each is effected ſucceſſively, and in a time proportionate to the quality of the powder, the ſize of the grains, &c. and ſince on the other hand the force of powder depends principally on a permanent fluid generated at the exploſion, the elaſticity of which is increaſed by the preſence of fire: it follows that this force increaſes continually from the inſtant that the inflammation commences, till all the powder be conſumed, and then is quickly reduced by the decreaſe of heat, to the ſimple elaſticity of the permanent fluid. There is then a period when the degree of heat is moſt intenſe; but this varies even in powder of the ſame quality, when fired under different circumſtances. As no general and conſtant law can therefore be eſtabliſhed, we muſt be content with aſcertaining the greateſt degree of force in particular caſes; which founded on certain data, may be uſefully applied to the various ſervices of artillery. But that none of the moſt material points involved in the ſolution of this problem may be paſſed over in ſilence, nor any vain hypotheſes and chimerical ſuppoſitions formed; let us in the firſt place examine the force of powder in its moſt ſimple ſtate, that is, when reduced by the temperature of the air, to the elaſticity only of the permanent fluid, and afterwards in its moſt complex ſtate, that is to ſay, at the inſtant of exploſion.

CHAP.

## CHAP. I.

### THE METHOD OF MEASURING THE DENSITY AND ELASTICITY OF THE PERMANENT FLUID, GENERATED FROM FIRED POWDER, WHEN REDUCED TO THE TEMPERATURE OF THE ATMOSPHERE.

114. TO meaſure the abſolute elaſticity of the permanent fluid, there ſhould be no communication between the powder and the atmoſphere, either during or after the exploſion. But it is impoſſible to aſcertain the exact degree of preſſure of the fluid in a cloſe veſſel the inſtant after the exploſion, as its force is then increaſed by the heat that remains in the veſſel: nor can a more preciſe knowledge be obtained by delaying the experiment, till the internal air be reduced to the ſame temperature with the external; as a part of the fluid is abſorbed by the ſmoke and vapour: the abſolute force therefore cannot be aſcertained, but the following experiment will give the moſt accurate approximation.

FIG. VI. This machine ſeparates as much as poſſible, the permanent fluid from the ſmoke, ſulphureous vapour, and caput mortuum of the powder, and diminiſhes conſiderably the action of the heat that remains in the veſſel.

A A B B, is a cube of braſs, of which the two ſides A A B B are cylinders terminated by portions of ſpheres: A A, is made to receive the ſcrew E E of another hollow cylinder E D D E. F G L are copper veſſels of different ſizes, which ſcrew on to B B; H I H is a ſmall cylinder of braſs faſtened to the cube A B, by two ſcrews H H; within it is a piſton K, nicely fitted, which by means of the ſcrew I, opens or ſhuts the pipe *o o*, *p p*, that communicates between A A, B B. M N N M is a parallellipipedon of braſs fixed to the cube A B by the ſcrews M M, and the little pipe *q q* correſponds to *r r*. S R S is another paralellipipedon of the ſame metal, hollowed in the form of a cylinder; the opening *t t* is filled with a glaſs veſſel, containing a coloured liquor, the ſurface of which, &

may be diſtinguiſhed through the glaſs. At the upper part of the parallellipipedon is an aperture R, by which the external air communicates with the inſide of the veſſel. V W is a long glaſs tube, open at both ends; it is attached to a plate of braſs X X which is faſtened to S R S, and graduated in the ſame manner as a barometer: *y y* is a ſcrew made to turn very nicely in the lower part S S of the parallellipipedon S R S, by means of which the ſurface & of the liquor contained in the glaſs veſſel can be raiſed or lowered at pleaſure. When S R S is faſtened to M N N M by the ſcrew 16 of an iron pipe 2, 3 ſcrewed on to M N N M at 4, 4, the hole R correſponds exactly with *q*: 10, 12, 10 is a ſolid cylinder of braſs, with a little cavity 12 to hold the powder for the experiment; it is placed in the hollow cylinder E D D E, ſo that its baſe 10, 10 reſts upon the ledge 11, 11, in *A*, 11, A: its diameter 17, 17 ought to be about $\frac{1}{4}$ of an inch leſs than the interior diameter 18, 18 of the cylinder E D D E: 5, 7, 9 is a piece of iron that ſcrews into D D at 7 7; the inſide is ſpirated to admit the ſcrew 8, 6, 8 at 5.

For the ſake of making the experiment with more eaſe, the cube A B is faſtened to a circular bar T T of any metal, made as high as may be neceſſary for the purpoſe of applying the different veſſels F G L and ſcrewed on to a table or other convenient place at *m m*.—

115. For the experiment, apply R S to N N and ſcrew on the recipient F G L to B B. Place the cylinder 10, 12, 10 upon the ledge 11, 11, and having put the proper quantity of powder into 12, ſcrew the cylinder E D D E to A A. At 9 of the piece of iron 5, 7, 9 lay a thin ſheet of lead, and when 5, 7, 9 is ſcrewed on to D D let fall in 5, 9 a hot ball of iron, which will be retained at 9 by the ſheet of lead. Inſtantly ſcrew 8, 6, 8 into 5 by the handle 13, 13, ſo that 8, 8 may exactly fit 14, 14; the point 6 puſhes the iron ball into the cavity 12 containing the powder, and 5, 9 is exactly cloſed by 8, 6 before the exploſion can take place. When the powder is totally conſumed, draw back the piſton K by means of the ſcrew I which opens the pipe *o o*. The elaſtic fluid generated at the exploſion, ſoon ſpreads from the upper cavity into the pipe *o o*, paſſes through *p p* into B L B; thence riſing through *r*, *r*, *q*,

*q* it

9 it passes through the hole R into the glass vessel, and presses upon the surface & of the liquor contained in it. This pressure makes the liquor rise suddenly in the tube V W, after some undulations it fixes at a height proportionate to the quantity of powder.

116. If the height of the water in the tube when the undulations cease be remarked, and the machine remain in the same state, it will be found on observing it, after equal intervals of time, that the water continues sinking; but less after the second interval than the first, and less after the third than the second, till at length the alteration becomes imperceptible, except a very long interval be suffered to elapse. At the end of twenty-four hours, the liquor remains stationary in the tube, affected like the thermometer, only by heat.

These undulations arise from the smoke of the sulphur and the caput mortuum of the powder, having absorbed a part of the elastic fluid: the absorption is considerable at first, but its effects gradually diminish. On comparing the height of the water when it becomes stationary with its heighth, when the undulations ceased, the difference will denote the quantity absorbed by the smoke, &c. If the instant the undulations cease, the communication between the upper and lower cavities be closed by the piston K, the water stops suddenly, and never varies in height, unless affected by some alteration in the temperature of the atmosphere; if, after some time, the communication be again opened, the water will suddenly sink in the tube, because the elastic fluid contained in the lower cavity, rises to re-establish an equilibrium with that in the upper one, a part of which has been absorbed by the smoke and caput mortuum.

117. It will not be amiss previous to the experiment, to make a few physical observations on the effects observed above, and give some of the motives that influenced the particular construction of the machine. When the quantity of powder consumed in the experiment is $\frac{1}{360}$ of what the upper cavity could contain, if the cylinder E D E be taken off when the machine is perfectly cool, the smoke and caput mortuum will be found attached to the upper part D D of the cylinder E D E, and to the upper part 12 of the other cylinder 10, 12, 10; the action of the fire will have changed the colour of the latter, from its extremity 12, to about one third of its length, while no mark of the fire or smoke ap-

pears at the other extremity A 10 A, nor in the recipient F G L. This proves that when the communication between the two cavities by the piſton K is opened, the elaſtic fluid ſpreads itſelf without mingling with the ſmoke; therefore, the ſinking of the ſurface of the water in the tube, when the communication between the two cavities is open, and its ſudden fixation when it is ſhut, can only be attributed to the abſorption of a part of the elaſtic fluid, by the ſmoke and caput mortuum (116): it was neceſſary then to form a communication between the cavities, by this or ſome ſimilar contrivance.

If inſtead of $\frac{1}{300}$ of the powder that the upper cavity could contain $\frac{1}{150}$ be burned, the only difference will be, that the mark of the fire and ſmoke will deſcend nearer to the ledge 10, 11, 10, yet without entering the pipe *o o*. But, if a much greater quantity of powder be uſed, a part of the ſmoke will accompany the fluid into the recipient, on the opening of the communication, abſorb a part of the fluid, and diminiſh its preſſure on the ſurface of the liquor.

The cylinder 10, 12, 10, is deſigned to leſſen the action of the heat upon the fluid, and prevent the ſmoke from penetrating into the recipient; for,

1. If the powder be fired in A 11 A inſtead of 12, a part of the ſmoke and caput mortuum, would readily paſs through the pipe *o o* into F G L, and not only abſorb a part of the elaſtic fluid, but alſo clog up the piſton K when wanted to ſtop the communication.

2. The cylinder 10, 12, 10, increaſing the ſuperficies of the upper cavity, and the fire acting upon a greater number of phyſical points, the heat being thus communicated to a larger maſs is leſs, as is ſhewn in the 1ſt part, chap. 1.

3. As the heat ariſing from the inflammation of the powder, and the hot ball is almoſt entirely concentrated in the cavity 12, D, E, and conſequently acts upon a part only of the internal air and the elaſtic fluid, it increaſes the elaſticity much leſs than it would do, if communicated to the fluid and air contained in the whole cavity. This is not only agreeable to the preceding theory of fire, but may be further proved by this machine, in the following manner. Having diſpoſed all the parts of it properly, without putting any powder in 12 open the communication, and let

fall

fall into 12 a red hot ball; the heat expands the air in the cavity, and makes the water riſe in the tube. Having remarked its height, take away the cylinder 10, 12, 10, and repeat the experiment, the ball in paſſing through A D A to fall into A 11 A, rarifies the column of air that it contains, ſo much that the water riſes in the tube 15 or 20 times higher, than in the former experiment; but deſcends ſuddenly, and fixes at a point only three or four times higher.

118. Having explained the conſtruction of the machine, the combination of its parts, and the effects that powder has on it, is neceſſary to examine;

1. If the elaſtic fluid can eſcape. This may be aſcertained, by condenſing a certain quantity of the air in the machine, and obſerving while it is in that ſtate, if the alterations in the height of the water in the tube, and thoſe in a thermometer placed near the machine, differ.

2. The quantity of ſaltpetre equal to the contents of the upper cavity to the piſton K, and of the lower one from K to the ſurface of the water contained in the glaſs veſſel taken together ſhould be known. To find this, weigh the quantity of water that will fill the two cavities: in our machine, it was equal to 16580 grains. Now as the ſpecific gravity of water is to that of ſaltpetre as 10: 19, the laſt term $\frac{19 \times 16580}{10}$ expreſſes the quantity of ſaltpetre equal in bulk to the contents of the two cavities.

119. To begin a courſe of experiments; put ſo ſmall a quantity of powder into 12, that the ſmoke will not paſs from one cavity into the other; then having properly arranged all the parts of the machine, and cloſed the communication, drop the hot ball into the canal 5, 9, where it will be retained by the ſheet of lead. Inſtantly ſcrew on 8, 6, 8 which exactly cloſes up the canal 5, 9 and puſhes the ball into 12 to fire the powder: then open the communication between the two cavities, and when the undulations of the water in the tube ſubſide, cloſe it again. When the water riſes in the tube, the ſurface & in the glaſs veſſel ſinks: raiſe it by turning the ſcrew *y y*, till it reaches the point it was at before, in order always to preſerve

the lower cavity in the ſame ſtate. Obſerve the height of the water in the tube V W, meaſuring it from the ſurface & deducting the augmentation proceeding from the attraction of the glaſs. The effects of this attraction are known previous to the experiment, by noting how much the water contained in the tube, is higher than the ſurface & This experiment ſhould be repeated ſeveral times in the ſame manner, with equal quantities of powder of the ſame quality, in preciſely the ſame ſtate of the atmoſphere, obſerved by a very accurate thermometer; and the elevation of the water in the tube at each time remarked. Neither the recipient F G L nor the cylinder E D E ſhould be ever touched with the naked hand, but with a folded napkin, for the contact even of a finger would in a ſhort time excite a degree of heat ſufficient to raiſe the water in the tube. After ſeveral repetitions, take the mean height; thus the varieties occaſioned by the abſorption of a part of the fluid, and the heat remaining in the machine may be accounted for. Call this mean height $a$, and the mean height of a barometer filled with the ſame kind of liquor as the glaſs veſſel A; the fraction $\frac{a}{A}$ will expreſs the ratio between the elaſticity of the fluid produced from the powder, and that of the atmoſpheric air.

120. In ſmall quantities of powder the proportion between the ſaltpetre and the other ingredients may not be exactly the ſame as in a larger maſs; which in a ſeries of experiments may cauſe a conſiderable variation in the elevation of the water in the tube. To remedy this inconvenience, grind ſome ſaltpetre, ſulphur, and charcoal ſeparately; weigh the ſaltpetre and mix it with ſuch a quantity of the other two ingredients as will moſt quickly conſume it. The mixture need not be granulated, as the elaſticity and denſity of the fluid are the only objects of reſearch in this experiment; the phlogiſton being only employed as the means of decompoſing the nitre.

121. The elaſticity of the fluid, though very much dilated in the two cavities is exactly proportionate to its denſity: thus the fraction $\frac{a}{A}$ expreſſing the elaſticity $= n$ will alſo expreſs the denſity. Now ſuppoſing the contents of the two cavities

cavities taken together $=c=\frac{19\times 16580}{10}(118)=31502$ grains,

and the ſaltpetre made uſe of in each of the experiments $=f$;

then $\frac{nc}{f}$ will expreſs the denſity of the fluid contained in a

ſpace $=f$. But the non-elaſtic ſubſtances $=m$ which are in the ſaltpetre muſt be deducted from $f$, call their bulk $=rm$;

then $f-rm$ will expreſs the quantity of the fluid, and $\frac{nc}{f-rm}$

will expreſs the denſity of the elaſtic fluid when confined in the ſaltpetre.

122. The ſpecific gravity of the fluid generated from nitre is ſuppoſed to be equal to the atmoſpheric air. Then ſince the ſpecific gravity of air to ſaltpetre is as 1 : 1520, and the contents of the two cavities taken together are equal to a quantity of ſaltpetre $=c$, the quantity of air in the machine (Fig. 6.) capable of producing an effect $n$ equal to that of the fluid $f-m$ will be repreſented by the expreſſion $\frac{nc}{1520}$. Then $f-m=\frac{nc}{1520}$; and ſubſtituting in this equation, the known values $c=31502$, $f=6$ grains, $n=\frac{2}{21}$, that of $m$ will be $=4$ grains; and as the quantity of elaſtic fluid contained in nitre is proportionate to its maſs (57), it will be expreſſed by the ratio $\frac{f-m}{f}=\frac{1}{3}$ of the maſs of ſaltpetre. It does not follow, becauſe the ſpecific gravity of this fluid is equal to the atmoſpheric air, that it has all the other properties of it; much leſs that it is pure air: For it has been proved in the former part of this work, that the greater the rarefaction of the air, the more difficultly powder is fired. Now the elaſtic fluid generated from the firſt burnt grains not ſupplying the want of natural air, we muſt at leaſt allow, that at the firſt inſtant of its generation it is deprived of the property which the aerial fluid poſſeſſes, of accelerating the burning of combuſtible bodies. It would be a reſearch foreign to our purpoſe, to enquire whether the elaſtic fluid does or does not acquire this property ſome time after its production.

123. In the theorem $\frac{nc}{f-rm}$ (121), if the known values of $c$, $n$, $f$, $m$ be ſubſtituted, and $r=\frac{19}{27}$; that is to ſay, if the denſity of the non-elaſtic ſubſtances be equal to the denſity of the fixed nitre, $\frac{nc}{f-rm}=942$; the denſity of the elaſtic fluid is then 942 times greater when incloſed in the ſaltpetre, than when in equilibrio with the preſſure of the atmoſphere.

124. The quantity and denſity of the elaſtic fluid contained in ſaltpetre being known, it will be eaſy to find the denſity of that generated from a quantity of powder fired in a cloſe veſſel. Suppoſe the veſſel be expreſſed by a maſs of ſaltpetre, the weight of which $=G$; the elaſtic fluid will $=\frac{G}{3}$ the non-elaſtic ſubſtances $=\frac{2G}{3}$, and their maſs $=\frac{38G}{81}$ (122). Thus $G-\frac{38G}{81}=\frac{43G}{81}$, will be the volume of the fluid $\frac{G}{3}$.

If the quantity of powder fired in the veſſel G be expreſſed by $b+p$, where $b$ denotes the quantity of fluid contained in the powder, and $p$ the ſulphur, charcoal and fixed nitre; and after the exploſion, the maſs of non-elaſtic ſubſtances $=qp$, then the volume of the fluid, after the powder is fired, will be $G-qp$. Now, if the value of this fluid was $=\frac{G}{3}$, its denſity in the volume $G-pq$ would be to its denſity in the volume $\frac{43G}{81}$ as $\frac{nc}{f-rm}:\frac{nc}{f-rm}\times\frac{43G}{81\times G-qp}::942:942\times\frac{43G}{81\times G-qp}=\frac{500G}{G-qp}$. But if the volume of the fluid be only $b$, then the proportion will be $\frac{G}{3}:b::\frac{500G}{G-pq}:\frac{1500b}{G-pq}$ the denſity required. For example, ſuppoſe the veſ-

ſel

G be filled with war powder: From the composition of this powder $p=3b$, and a vessel which could contain a quantity of saltpetre = G is filled with a quantity of powder weighing $\frac{15G}{38}$, and the value of $q$ is known by other experiments = to about $\frac{7}{9}$: then $b+p=4b=\frac{15G}{38}$; now substituting in the place of $b$ the numbers and values of G and $p$, $\frac{1500b}{G-pq}=\frac{1500b}{G-\frac{7b}{3}}=\frac{1500}{\frac{152}{15}-\frac{7}{3}}=192$, that is to say, the density of the fluid produced in the vessel G is equal in this case to 192 times the density of the same fluid when its elasticity is equal to the mean pressure of the atmosphere.

125. To determine the elasticity of the fluid generated from a given quantity of powder fired in a close vessel, one of these two theorems

$$1st,\ 9962nS;\quad 2d,\ 9962S\times\sqrt{\frac{3}{2}m-\frac{3}{2}\sqrt[3]{m\times\overline{m-n}^2}},$$

may be used: the first when the density of the fluid is less than 20; the second when it exceeds 20: in the first case, it will be sufficient to find, according to the method laid down in the preceding paragraph, the value of the density of the fluid, then substituting this value in the place of $n$ in the first theorem, the pressure of the fluid against a superficies S will be expressed in pounds. In the second theorem, instead of $m$ insert 942, which expresses the density of the fluid when inclosed in the nitre (123); and instead of $n$, the value of the density of the fluid generated from the nitre found as in the preceding paragraph. Then the pressure of the elasticity of the generated fluid on a superficies S will be expressed in pounds.

CHAP.

## CHAP. II.

### The Methods of Measuring the greatest Force of fired Powder at the Instant of Explosion in a Vessel that can neither increase in Size nor alter in Form.

126. If it be so difficult to measure the elasticity of the permanent fluid in its most simple state, how little reason is there to expect, that its force at the instant of explosion can be ascertained with precision, when the fluid is greatly complex, and when from various causes, its elasticity may be increased or diminished. In fact, it is impossible to define either the quantity of fluid generated at each instant of the inflammation, the intensity of the fire, or the manner in which it spreads and propagates itself among grains of different kinds of powder, or even of the same, when used under different circumstances; the degree of rarefaction in the common air contained within and between the grains, the elasticity of the smoke, and the increase of elasticity in the permanent fluid arising from the pressure of the substances, relatively considered as non-elastic, when expanded by the action of heat, are equally unknown.

The solution of so involved a problem would seem to surpass human skill, since from the short duration of the phœnomenon, the numerous circumstances that affect it cannot be analysed; as no method can be devised of assigning the exact quantity and force of each, either by separating at the instant of inflammation the smoke from the other parts, preventing the expansion of the non-elastic substances, or observing the law in which the fluid is generated. The utmost we can do is to ascertain the greatest force resulting at the instant of inflammation from the reunion of all these causes, by the help of such principles as we may be able to establish. To avoid entering into too long a discussion, let us suppose the powder to be fired in a vessel so completely filled, that no void space be left, except the interstices between the grains. There are three different cases in which powder may be fired:

1. In

1. In a veſſel that cannot increaſe in ſize or alter in form, with the vent cloſed at the beginning of the exploſion.

2. In a ſimilar veſſel, with an aperture left for the eſcape of the fluid.

3. In a veſſel which by the force of the exploſion expands or increaſes in ſize, and affords an iſſue to the fluid.

It is evident, that on firing equal quantities of powder of the ſame quality, in veſſels perfectly equal in every reſpect, the degree of force will be greater (113.) in the firſt caſe than in the ſecond or third, and in the ſecond than in the third.

127. The firſt caſe can never occur in the uſes to which powder is applied in military operations. The ſecond happens ſometimes in the chambers of mines, where the ſurrounding ſubſtances do not yield to the exploſion; and in ſhells and grenades, whoſe reſiſtance is ſufficient to put them in equilibrio with the action of the powder. The third caſe ariſes in the chambers of mines, made in ſubſtances ſuſceptible of impreſſion, and in fire-arms loaded in the cuſtomary manner.

The principal methods of meaſuring the greateſt force of fired powder in the ſecond caſe will be treated of in this chapter, and in the ſubſequent ones, the method of meaſuring it in the third caſe: confining our obſervations however to its effects on fire-arms; ſince in the third book of Military architecture, and in the Treatiſe of Artillery, the application of powder to mines is amply diſcuſſed.

128. To meaſure the greateſt elaſticity of the fluid produced from fired powder, it may be compared with the three following reſiſtances, the weight, coheſion, and elaſticity of bodies. It has been found from experiment, that the greateſt elaſticity of powder fired in an invariable veſſel, from which the elaſtic fluid can eſcape by the vent (126. N° 2.) is equal to about 1800 times the mean preſſure of the atmoſphere: the machines therefore for meaſuring the greateſt force of different powders (40.) muſt be capable of a very great reſiſtance, and the weight to expreſs the force, very conſiderable, which renders it extremely difficult to conſtruct ſuch complicated machinery, with the requiſite exactneſs and accuracy.

129. If

129. If to reduce the weights, or ſimplify the machinery, the quantity of powder be leſs than the veſſel could contain, the fluid produced at the commencement of the inflammation, being diffuſed through the whole veſſel, will not be expoſed to the ſame degree of heat, as if the veſſel were full, and the powder burning in each point. Thus with equal quantities of powder, the elaſticity will be in proportion to the ſize of the containing veſſels; and in veſſels of equal contents, in proportion to the quantity of powder. Therefore, to aſcertain the greateſt elaſticity from the effects of a ſmall quantity of powder fired in a large veſſel, it will be neceſſary to repeat the experiment with different quantities of powder, till the maximum be diſcovered.

130. The form of the veſſel ſhould be ſuch, as to admit of the powder being ſo collected, that the whole may take fire in the ſhorteſt time poſſible, and act inſtantly upon the ſurface of the reſiſting body, whoſe motion is to determine the preſſure of the fluid: For if it be not in contact with the mobile, inſtead of an action of preſſure, it will be an action of impulſion, and the force communicated will be much greater, than is the preſent object of this reſearch: to render the experiment concluſive, this circumſtance muſt be carefully attended to.

131. In the common mode of proving powder with the ſmall mortar, the weight of a globe is oppoſed to the exploſion: but this method cannot aſcertain the greateſt elaſticity, for the globe being proportionally too light, is put in motion before the full force of the powder is produced.

The *eprouvette*, is a vertical machine invented long ago, for comparing the force of different kinds of powder by means of weight. But to aſcertain (Fig. 7.) the greateſt elaſticity, the weight Q M N Q S ought to be much heavier than it generally is; it ſhould only yield to the impelling power when the elaſticity is at its higheſt degree, and be raiſed juſt enough to ſhew that it has given way to the action of the fluid. The weight may be increaſed or diminiſhed at pleaſure, by making it hollow in Q S Q and putting in any heavy ſubſtances that can be uniformly arranged, as ſmall ſhot, &c. which will preſerve the centre of gravity in the vertical axis S T of the cylinder: at the ſides of the eprouvette two channelled uprights ſhould be placed ſo that when the body Q M N Q is raiſed, the teeth L L may ſlide perpendicularly in the grooves.

132. The

132. The theorem $9962\ n\ S = P$ where $n$ expreſſes the elaſticity of the fluid, and S the ſurface acted on, ſhews that if in this eprouvette the diameter E F of the cylinder be $\frac{1}{12}$ of a foot, S will be $= \frac{1}{7.7.8}$: then ſubſtituting 1800 in the place of $n$, $9962\ n\ S = 9962 \times 1800 \times \frac{1}{7.7.8} = 23048$lbs: the weight Q M N Q ſhould not be leſs, that it may juſt yield to the action of the fluid in its higheſt ſtate of elaſticity; but as ſuch a weight is very ponderous and unmanageable, it may be meaſured by a lighter maſs, by leſſening the value of S without diminiſhing the ſize of the cylinder, as follows:

133. In the eprouvette A B C D, make a hollow cylinder C I K D of ſuch a depth, (Fig. 8.) that on applying the ſcrew G C P D H of a ſufficient length to reſiſt the greateſt efforts of the powder, the height G I of the ſpace I K G H be nearly equal to the diameter G H. In the centre of the ſcrew drill a cylindrical canal O P, and introduce a pin of poliſhed iron of the ſame form, fitting ſo exactly that the fluid cannot paſs between it and the ſides of the canal, with a ledge at P to prevent its falling into the chamber where the powder is lodged; the axis V P of the cylinder being vertical, place upon the head of the iron pin a weight of which the centre of gravity is in the axis V P with teeth to ſlide up and down in the grooves of two uprights parallel to V P as in (Fig. 7.) Having filled the ſpace G I K H with powder, and applied fire by the vent X, the elaſtic fluid acting on every point of the ſuperficies, will raiſe up the pin O P, and conſequently the ſuperincumbent weight; which may be increaſed or diminiſhed (131) till the force of the powder be only juſt ſufficient to raiſe it. The height to which it is raiſed, will ſhew the preſſure of the fluid, for the weight being expreſſed in pounds, the value of S is equal to the baſe O in the pin O P. Thus the value of $n$ expreſſing the elaſticity of the fluid may be eaſily found.

134. There are different methods of aſcertaining the greateſt force of powder, by the coheſion of the conſtituent parts of bodies. For example, fill with powder a cylinder of homogeneous metal, the ſides of which are of equal thickneſs, ſecure the ends ſo firmly with ſtrong ſcrews that they will reſiſt the utmoſt force of the fluid, and ſet fire to the powder by a ſmall vent made in the middle of the length of the cylinder, that the inflammation may be as ſudden and general as poſſible. The veſſel will then burſt longitudi-

nally

nally, and the equilibrium between the reſiſtance of its ſides, and the greateſt elaſticity of the fluid will be known.

The theorem for finding this equilibrium is $996 n r = m q$ where $r$ repreſents the radius of the cylinder, $m$ the thickneſs of the ſides, $q$ the number of pounds requiſite to make a breach of a foot in length, whatever be the coheſion of the metal that the cylinder is made of. Now as $r$ and $m$ are known quantities, and the value of $q$ may be known by experiments on the pieces of metal broken off from the cylinder, by ſubſtituting them in the theorem, the value of $n$ which expreſſes the greateſt elaſticity of the fluid will be found. It may be obſerved, that theſe experiments ſucceed better, when the cylinders are at firſt thicker than neceſſary, and are thinned a little after each diſcharge, till they are ſo reduced as to yield to the exploſion of the powder.

135. With the following machine, the elaſticity of powder may be meaſured upon the principles of coheſion. A B C D is a cylinder of bronze or iron, (Fig. 9 and 10.) within which is a cylindrical cavity E F G H to contain the powder, it can be cloſed by means of the ſcrew I E F K, equal in length to about $\frac{2}{3}$ of the diameter E F, and perforated with the vent L M. Put into a cylindrical canal made at G H an iron pin O P well tempered and poliſhed to preſs perpendicularly on a piece of tempered iron Q Q. S S is a bar of iron thinner in the middle X Y than at the extremities, which are pierced with two holes, 8, 8, to admit the iron legs R T, firmly united to the cylinder A B C D. Below the iron bar is laid a plate of lead W W, covering another bar of iron V V, and the whole is firmly ſcrewed together by the nuts Z Z. On ſetting fire to the powder incloſed in the ſpace E F G H, the inflamed fluid preſſes on the head O of the pin O P, and conſequently on the piece of iron Q Q, which reſting on the thin part of the bar S S, endeavours to break it; which it effects when the action of the powder is greater than the reſiſtance of the bar. The plate W W and the bar V V ſtop the iron pin O P when the bar is broken; thus E F G H is altered as little as poſſible.

Repeat the experiment with an equal quantity of the ſame powder, but make the bar S S at each time of a different thickneſs in X Y, till it yields with great difficulty to the action of the fluid; then apply a bar equal in thickneſs to the laſt, and raiſing the machine by the trunnions 10, 10, faſten

it

it at a proper height; ſuſpend from *o o* by the hooks 12, 12, and the chain 11, a baſon loaded with different weights till the bar breaks. The weight neceſſary to overcome the coheſion of the bar S S being thus known, in the theorem $9962nS = P$ put its value expreſſed in pounds, and ſubſtitute in the place of S the value of the pin O P, then the value of *n* will be found.

136. This machine may be combined in another manner. Inſtead of the canal O P, and the other parts placed below C D; 2, 3, is a cylindrical cavity, which is exactly filled with an iron pin 2, 3, in contact with an iron plate, 5, 5, let into the thickneſs of metal of the cylinder, the exterior ſide of which, 4, 4, is even with the ſuperficies of the cylinder. 6, 7, is an iron ring which goes round the cylinder A B C D, fitting it exactly oppoſite to 2, 3, and ſo proportioned that the interior ſurface touch the plate of iron 4, 4. After each diſcharge, the ring is filed in the part 7, 7, till it gives way to the action of the powder; taking care to place the machine contiguous to a ſolid body, that it may confine the plate 4, 5, and 2, 3, after breaking the ring, for reaſons already pointed out. The proper thickneſs for the ring having been determined, find the weight that can break another ring of the ſame metal and equal to it in thickneſs; for this purpoſe, apply the ring to a ſhort cylinder of hard wood of proper dimenſions; let the plate 4, 4, be longer than the wooden cylinder that the iron hook O, 11, O may be hung on the ends. Make uſe of the ſame plate, 4, 4, and the ſame ring, that the part which preſſes the ring may not be altered in form from the action of the weight that is to break it. When the weight = P is thus found, to know the elaſticity = *n*; a particular theorem muſt be conſtructed, in which muſt be inſerted the values of the pin 2, 3, of the radius of the interior circumference of the ring, and of the thickneſs of metal at the part where the ring broke.

137. It reſults from theſe experiments (133, 134, 135) that if a veſſel be filled with ſmall-grained powder without being compreſſed, the greateſt elaſticity = *n* will be equal in dry weather to 1900 hundred times the mean preſſure of the atmoſphere, and only 1400 when the air is much loaded with vapour; powder is therefore a kind of aerometer.

In this machine the diameter and height of the hollow cylinder were each $\frac{1}{2}$ an inch, and the contents about 3 drs.

From

From the principles eſtabliſhed in the former part of this work, it may be inferred that by increaſing to a certain point the ſize of the veſſel, and filling it with powder without increaſing the ſize of the vent, the elaſticity of the powder will be much greater than that found by the laſt experiments, as the fire will be more intenſe, and leſs of the elaſtic fluid in proportion to its maſs will eſcape. To aſcertain to what degree the elaſticity will increaſe when powder is fired in a veſſel with the vent cloſed, a ſimilar method may be uſed (111).

FIG. ix. Perforate the ſcrew IEFK with a canal LM, to receive the ſcrew G&, which may be turned with velocity by the winch NN. The ſcrew G&, muſt be longer than the canal LM, that as ſoon as its head exactly correſponds with the ſuperficies IK, the point & which has been heated red hot, paſſing through the orifice M, may fire the powder contained in EFGH.

138. From theſe methods of proving the force of powder by weight and coheſion, added to the obſervations on the ſubject in the Philoſ. Inſtit, there will be no difficulty in applying elaſticity to the meaſurement of this force (127). A ſpring ſtrongly bent oppoſed to the movement of the iron pin will ſuffice for this purpoſe; but the greateſt force of the powder ought only to increaſe the tenſion of the ſpring enough to make an impreſſion on ſoft wax, or ſome ſimilar ſubſtance.

139. We will conclude this chapter with remarking the difference obſervable in the activity of fire on burning equal quantities of powder in veſſels of different ſizes. Fit a ſcrew EMNF to the part CDHG of the eprouvette, (Fig. 8.) and perforate it with a ſmall canal TY; at the bottom of the ſcrew make a cavity in form of a truncated cone MRSN, and fill it with tin perforated through the middle, ſo as not to ſtop up the cavity TY: having cloſed the vent XI, and filled IKGH with powder, apply the ſcrew EFMN, and ſet fire to the powder by TY, through which all the elaſtic fluid muſt of neceſſity paſs. On unſcrewing EFMN, a part of the tin will be found melted. To collect the quantity melted in this experiment, a rough plank ſhould be placed about a foot diſtant from TY, and after the exploſion, the melted ſubſtance will be found ſticking to it. On burning the ſame quantity of powder in a veſſel much larger, the tin will not melt, and if it be burned in the open air upon a ſheet of paper,

per, the paper will ſometimes be but little damaged. This difference of effects proves how much the activity of the fire varies; hence, alſo the elaſticity of the fluid muſt have altered very conſiderably during the courſe of theſe experiments. This will explain the reaſon why fire-arms ſoon become heated, and the vents enlarged after firing ſeveral rounds with wads ſtrongly rammed; while the ſame effects do not take place when the wads are lightly rammed, though the ſame quantity of powder be uſed with the ſame intervals of time between the diſcharges.

By the experiments with the ſcrew EFMN, the metal beſt adapted for making bouches for guns might be aſcertained. Make a troncated cone of each of the metals intended to be proved, and place it in MNRS; that which ſuſtains the action of the powder, with the leaſt alteration, is the beſt.

## CHAP. III.

### Of the Modifications in the Generation of the elaſtic Fluid in the cylindric Bore of Fire-arms, when an Obſtacle is preſented to it's paſſing through the Mouth of the Piece.

140. WHEN the charge is not too ſmall, nor the gun too long, the ſhot in paſſing from the charging cylinder to the mouth of the piece is impelled by freſh elaſtic fluid, which is continually generating. This accelerated motion is the effect of the preſſure of the fluid, whenever the ſhot has been ſtrongly rammed upon the powder; when it encounters other obſtacles as in rifled barrels; or, when at the commencement of its motion, the reſiſtance is equal or ſuperior to the impulſion of the fluid, which endeavours to expand itſelf towards the mouth of the piece. But if there be no reſiſtance; or only ſuch as the impulſion can eaſily overcome, as when the charge is not wadded, or but ſlightly; or when the wad over the powder is made of ſubſtances eaſily penetrable by the elaſtic fluid, as twiſted hay or ſtraw, the movement will then be the effect of impulſion. In the firſt caſe the velocity at each point of the length of the bore is in the ſubduplicate ratio of the ſuperficies, that expreſſes the ſum of the preſſures in the ſpaces paſſed through by the ſhot; but in the ſecond

it is compounded of this ſubduplicate ratio added to the conſtant quantity communicated to it by impulſion. (Philoſ. Inſtit.) The former as being of moſt general uſe (109) merits the firſt attention.

141. If the law of the generation of the fluid were conſtant, and the intenſity of the fire uniform, the ſcale of preſſures might be eaſily determined, and applied to fire-arms of all calibres; but theſe are ſo modified from a variety of circumſtances, that the reſult of all experiments affords a ſolution adapted but to particular caſes. Before we deſcend to particulars, let us examine under a general point of view the modifications that ariſe from the different degrees of reſiſtance oppoſed to the fluid; and adduce a few ſimple experiments to demonſtrate that the production of the fluid varies according to the reſiſtance oppoſed to its exploſion.

142. Theſe varieties ariſe not only from the maſs of the ſhot and wad, but alſo from their friction againſt the part of the bore contiguous to the charge. To increaſe the friction, they make uſe of wads that enter with difficulty into the gun, and are ſtrongly rammed upon the powder. By theſe means the powder is collected into a very ſmall ſpace cloſe to the vent, and burning with more rapidity, the force of the fluid is greater; provided that a ſufficient interval be left between the grains for the propagation of the fire.

143. Some dry reeds were cut into lengths and placed in three rows, each was numbered; and No. 1 of the firſt row was of the ſame length and diameter as No. 1 of the other two rows; and ſo of No. 2, 3, &c. They were charged with a quantity of muſquet powder equal to one diameter; thus the three of the ſame number had an equal charge. A bit of rag was lightly preſſed into thoſe of the firſt row; over the ſame kind of wad a leaden bullet was put in thoſe of the ſecond row; and into thoſe of the third, a ſimilar wad was ſtrongly preſſed without a bullet. The exploſion burſt all the reeds in the third, and more than half of thoſe in the ſecond row; but thoſe in the firſt remained entire, though they were fired four or five times in the ſame manner. Effects almoſt ſimilar took place in ſmall tin guns $\frac{1}{4}$ of a foot in length, and equal in diameter to a ball weighing $\frac{7}{8}$ of an ounce.

Now the only difference between theſe diſcharges was in the reſiſtance oppoſed to the iſſue of the fluid through the mouth

mouth of the piece; the weight of the bullet in the ſecond row, and the increaſe of friction in the third making the reſiſtance greater than in the firſt: whence, the greater the reſiſtance the greater quantity of the fluid is produced; and it may be further inferred from theſe experiments, that the reſiſtance from friction may exceed the reſiſtance proceeding from the *Vis Inertiæ* of the bullet. The uſual method of blowing rocks, proves how powerful a reſiſtance friction preſents: The miners after drilling a hole 6 or 8 inches deep, fill about half of it with powder, and the remainder with earth ſtrongly compreſſed; and ſet fire to the powder by a little ſauciſſon that paſſes through the earth. The friction and the adheſion of the earth to the ſides of the hole are ſo great, that the powder not being able to force a paſſage burſts the rock.

144. In the preceding experiments it was proved from the reſiſtance of cannon, that the elaſticity of the fluid is in proportion to the obſtacles oppoſed to the exploſion; this will be further demonſtrated from the velocity of the ſhot.

FIG. XI. Take three piſtol barrels equal in length; let the bores of two of them be exactly of the ſame diameter, but that of the third equal in diameter to the other two only in the part AB, which contains the charge, and diminiſhing in diameter from B to C, ſo that the leaden bullet P cannot paſs into BC without changing its form. To load this laſt piſtol, which we will call No. 3. unſcrew AF, and holding the piſtol vertically, put in the bullet and as much powder as will fill the chamber to A and all take fire; then ſcrew on AF: put into the other two piſtols equal quantities of powder of the ſame quality, and bullets of the ſame diameter and weight as in No. 3; in No. 1. preſs a wad lightly over the powder; but in No. 2. ram down a very high wad, to touch the powder but not to compreſs it ſo as to diminiſh its bulk, which ſhould be equal in the three barrels. On firing them againſt the ſame butt, the bullet from No. 2 will penetrate deeper than that from No. 1; and the bullet from No. 3. much deeper than that from No. 2.; the bullet of No. 3. will penetrate as deep as a bullet fired from a piſtol twice or thrice as long and charged as No. 1.

145. Having thus ſhewn that alterations in the reſiſtance produce very conſiderable modifications in the production of

the fluid, in proof of which many other experiments might be adduced, let us now examine them; and for the ſake of rendering the reſearch leſs difficult, ſuppoſe;

1. That the charge is always collected together in the ſame manner at the bottom of the cylinder; the gun always fired in the ſame direction; and the reſiſtance oppoſed to the exploſion expreſſed by the weight of a cylindrical body, of a calibre exactly fitted to the bore of the gun: then the reſiſtance will be in proportion to the length of this body.

2. That all the grains take fire, but are not totally conſumed before the reſiſting body begins to move; which experience proves to be the caſe with moderate charges, when a ſufficient reſiſtance is oppoſed to the exploſion.

FIG. XII. Let the part AE in the cylinder ABCD, cloſed in AC, be filled with powder; and R expreſs the reſiſting body contiguous to the powder in E. If all the elaſtic fluid be generated before the body R begins to be ſenſibly in motion, and in paſſing from E to B preſerve the ſame degree of heat; the preſſure of the fluid in AE would be the ſtrongeſt poſſible. Expreſſing this preſſure by the line EF, drawn at right angles to AB, the preſſures of the fluid in the ſpaces AH, AG, AI, will be expreſſed by the perpendiculars HL, GM, IN, &c. which with EF will reſpectively be in the reciprocal ratio of the diſtances AE, AH, AG, AI, and a line paſſing through the extremities F, L, M, N, O, will be an equilateral hyperbola between the aſymptotes AB, AW; ſuppoſing the fluid to be ſubject to no other modification than expanſion.

146. It has hitherto been ſuppoſed that all the elaſtic fluid is generated before the projectile begins to move, and that the intenſity of heat cauſed by the entire conſumption of the powder ſuffers no diminution. But the ſecond part of this ſuppoſition is evidently impoſſible, for in powder of a good quality all the fluid is not diſengaged before the whole of the nitrous and combuſtible particles are conſumed, the heat muſt therefore decreaſe, as ſoon as the fire is extinct, in proportion to the expanſion of the fluid. Wherefore, the preſſures in the points H, G, I, K, will be neceſſarily leſs than the correſponding perpendiculars HL, GM, IN, KO, &c. The firſt poſition is only admiſſible when the reſiſtance of the body

R is

R is equal to, or greater than the greateſt preſſure of the fluid in A E: but if R be not capable of reſiſting the action of the fluid, it will begin to move towards B as ſoon as there is a ſufficient quantity of elaſtic fluid produced to overcome its reſiſtance. Thus, not only the preſſure on each phyſical point of the ſpace A C E will be expreſſed by a right line ſhorter than E F; but if the weight of R be ſo diminiſhed, that it makes the leaſt reſiſtance poſſible, the line that will expreſs the preſſure of the fluid when R begins to move, will be the ſhorteſt of all the lines that can be drawn between E and F.

147. The column of air contained in the bore of the gun, and communicating with the external air, is the leaſt reſiſtance which can be oppoſed to the expanſion of the fluid.

Now expreſſing by E V the preſſure of the fluid that begins to move the reſiſting body, and by H T its preſſure in the ſpace A H, the line H T will be longer than a fourth proportional to A H, A E, E V, ſince the fluid in paſſing from E to H is continually acquiring greater elaſticity from the ſucceſſive generation of freſh matter. It will be the ſame with the lines that expreſs the preſſure in the ſpaces A G, A I, &c. till the powder be entirely conſumed: thus the line V T S 2 paſſing through the extremities of theſe perpendiculars, will be a ſcale to determine the limit of the weakeſt preſſure that the fluid can exert in the ſpace A B C D.

148. But when the powder is entirely conſumed, the proportion between the lines that expreſs the preſſure of the fluid will be changed. Suppoſe that all the grains are conſumed when the fluid reaches I, and that the preſſure in the ſpace A I be expreſſed by I 2, this line will be neceſſarily ſhorter than I N; for according to ſuppoſition, I N repreſents not only the effect of all the fluid, but alſo of the greateſt degree of heat that can be produced by the entire conſumption of all the combuſtible ſubſtances: but in I 2, if the maſs of the fluid be the ſame, the degree of heat is leſs, whence its elaſticity and of courſe its preſſure will be leſs: the ſcale V T S 2 can never touch the hyperbola F L M N O, which may therefore be conſidered as the limit of the greateſt preſſure of the fluid. When the fluid reaches K, the preſſure K Q will be leſs than a fourth proportional to A K, A I, I 2; for as no freſh fluid will be generated between I and K, and the heat is decreaſing, the elaſticity will be leſs. At 3 and the other points in ſucceſſion, the ſame reaſoning will hold good.

The ſcale of preſſures V T S 2 Q P beginning to form a curve at 2, the part 2 Q P will always approach the right line A B, till the fluid be equal in elaſticity to the atmoſphere; to eſtabliſh this equilibrium the gun would require to be of a very great length, if no part of the fluid could eſcape through the vent.

149. The ſcale will neceſſarily diverge from V towards 2; afterwards it will continue to diverge from, become parallel to, or converge towards A B, according to the quality of the powder, and other circumſtances that tend to modify its effects.

150. A greater number of grains are conſumed in A F, as the reſiſtance of R is the greater (145); thus the heat being increaſed in this part, the powder will be conſumed more rapidly, and the nearer to A E, will be the point where all the combuſtible ſubſtances are conſumed. The true ſcale of preſſures will then be between the aſſigned limits (147, 148, 149), without touching them, till the powder be totally conſumed. No general rule can be laid down for the proportion in which the increaſe of heat accelerates the burning of the powder in paſſing along the bore of the gun, from the many circumſtances that concur to modify its effects, and the impoſſibility of aſcertaining ſome of them. Vide 1ſt part.

151. The preſſure of the fluid in A E being proportionate to the reſiſtance of R; if the weight of R remain the ſame, the preſſure by which it will be ſet in motion without regard to the more or leſs rapid production of the fluid will not vary, whatever be the quantity and quality of the powder.

152. But the preſſures in the ſpaces A H, A G, A I, will be modified, not only by the quantity of elaſtic fluid generated in A E, but alſo by the quantity and quality of the powder and the ſize of the grains. Suppoſe that the charge A E has given a ſcale of preſſure X Y Z (Fig. 13.): reduce A E to K E and fill K E with powder of the ſame quality, and equally collected as A E; there will be the ſame preſſure E X, if R preſent the ſame reſiſtance (151). But in the ſpaces K H, K G, the preſſures H L, G M will be leſs than H Y, G Z. This equality of preſſure E X in the two charges ariſes from the ſame quantity of fluid being generated in the two ſpaces A E, K E before R began to move: if no freſh fluid were produced between E and H, ſuppoſing E H=

$EH = AE$, and $KE = \frac{AE}{2}$, the preſſure of the charge AE in the ſpace AH, would be to the preſſure of KE in the ſpace HK as $\frac{1}{2} : \frac{1}{3} :: 3 : 2$; ſince the elaſticity is in proportion to the denſity. But between E and H a freſh acceſſion of fluid is produced in both charges, and the greateſt quantity in the largeſt charge; ſo that the preſſure of the ſmalleſt charge in KH will be proportionally leſs than the preſſure of the larger in AH; the ſame may be obſerved of GZ, GM. If, on the contrary, AE be increaſed to EP, and filled with powder of the ſame quality, and equally collected as before, the reſiſtance of R remaining the ſame, the preſſure of the fluid EP will always be equal to EX; but the preſſure in PH, PG will be expreſſed by HN, GO longer than the correſponding lines HY, GZ.

153. On firing two powders of different qualities, AE and R remaining the ſame, the ſcale of preſſures produced by the firſt kind of powder being XYZ, that produced by the ſecond will likewiſe begin at X (151); but the remainder of the ſcale will paſs above or below XYZ, according to the rapidity with which the powder is conſumed in equal times, or to the greater or leſs production of the fluid.

154. From theſe remarks may be deduced the difference between two ſcales that expreſs the preſſures of the fluid in two guns of different calibres, charged with proportional quantities of the ſame kind of powder.

FIG. 14. Let ABCO, DHPM, be the cylindric bores of two guns, the calibre DM of the one 7 the calibre DB of the other: expreſs DM by D and DB by $d$; then the reſiſtance of the ſhot contiguous to the powder in N will be as $D^3 : d^3$; and the charges HN, CN will be in the ſame proportion: the perpendiculars that expreſs the preſſures NV, NX, will be as $D : d$; that is, as the diameters of the ſhot. For the number of phyſical points in the ſuperficies of the ſhot againſt which the elaſtic fluid acts, is in the duplicate ratio of the diameters, that is as, $D^2 : d^2$, thus, in the ſtate of equilibrium $NV \times D^2 = D^3$ and $NX \times d^2 = d^3$; then $NV : D :: NX : d$, and by tranſpoſition $NV : NX :: D : d$. But the ratio between the correſponding

ordinates L I, L Y will be greater than between N V, N X; for ſuppoſing the fluid in the ſpaces H P N, A C N to have the ſame degree of elaſticity, and the freſh fluid produced by the ſucceſſive inflammation of the grains between N and L to be proportional to the charges, a greater preſſure would be exerted in H P L than in A C L, as the fluid is more denſe in the former than in the latter: but the preſſure in H P N is already greater than in A C N, ſince they are in the proportion of N V to N X. Thus the preſſures being greater, and conſequently the fire being more intenſe, a greater quantity of elaſtic fluid will be generated in the larger cylinder between N and L; and at L its preſſure will be much greater than that in the ſmaller cylinder at the ſame point; conſequently the ratio of L I to L Y, will be greater than of N V to N X. This reaſoning is equally applicable to the point D in both cylinders: hence it may be inferred that the point where the powder is totally conſumed, is under the preceding circumſtances much nearer to the place occupied by the charge, in guns of large than of ſmaller calibre.

155. When the preſſure E X is equal to the reſiſtance R this latter may be expreſſed by (Fig. 15) E X; and will be proportional to the height of the reſiſting cylinder (145, No. 1) in guns of the ſame calibre, or to the diameters of the ſhot in guns of different calibres. With low wads not rammed with force, the line X F Z expreſſing the ſcale of preſſures will from the beginning ſenſibly diverge; but with wads ſtrongly rammed, the friction increaſing the reſiſtance, the ſcale of preſſures will be the line K H Y; in which the firſt preſſure E K is greater than E X, in proportion as the friction of the wads exceeds their weight; and all the ſcale K H Y will be farther diſtant from the axis E G than the ſcale X F Z: but though at the commencement of its motion K H Y diverges more from E G than X F Z, yet it ſoon converges towards it; thus its greateſt ordinate is much nearer the point E, than the greateſt ordinate of the ſcale X F Z.

It would be too tedious to enter into a detail of the ſeveral experiments that might be made in confimation of what has been advanced ſince the 150th paragraph; the reader by a little reflection will readily diſcern the principles on which our reaſoning has been founded; and from the ſequel, a ſimple practical

practical method may be deviſed of proving their force and juſtneſs.

156. Since the cylindrical bore of fire-arms ſhould be in equilibrio with the action of the fluid generated from fired powder, the thickneſs of metal muſt at every point of their length be proportioned to the ordinates of the ſcale of preſſure: this may be reduced to the four following caſes;

1. When the ſcale is parallel to the cylinder, the thickneſs of metal ſhould be the ſame throughout the whole length of the gun.

2. The ſcale may diverge from the axis A E G in advancing from E to G; or after diverging it may run parallel to the axis; in both theſe caſes there ſhould be the ſame thickneſs of metal from the breech to the muzzle, ſince the ſides muſt be in equilibrio with the greateſt ordinate.

3. It may from the point E diverge from the axis to a certain point, and then converge towards it; in this caſe, the metal ſhould be of equal thickneſs to the point of the greateſt ordinate, with which it muſt be in equilibrio; thence it may diminiſh in the ratio of the correſponding ordinates.

4. It may from the point E continually converge towards the cylinder; then the thickneſs of metal ſhould diminiſh proportionally from the breech to the muzzle.

157. The entire ſcale of preſſures can be deduced from the thickneſs of metal only in the fourth caſe; in the third caſe, that part of the ſcale only is known that converges towards the cylinder; in the two firſt, the greateſt preſſure of the fluid is only pointed out.

158. In muſquet charged with fire-work, fowling, or cannon powder, and the wads well rammed, the ſcale of preſſures is found to correſpond with actual experiment in the fourth caſe; and likewiſe in the third, if the wad be rammed with leſs force; ſince the greater this force, the farther from E where the charge is lodged, is the greateſt ordinate of the ſcale.

In the following chapter will be pointed out the method of determining experimentally the ſcale of preſſures in fire-arms of all calibres.

CHAP.

## CHAP. IV.

### OF THE INITIAL VELOCITY OF PROJECTILES, AND THE LAW UNDER WHICH THEY ARE IMPELLED FROM FIRE-ARMS OF CYLINDRIC BORES.

159. THERE are three methods of determining the initial velocity of projectiles: by deducing it from a knowledge of the line they deſcribe in their flight; by meaſuring it inſtrumentally near the muzzle of the gun; or by a third mode, which may be adopted whenever the thickneſs of metal is proportional throughout the length of the cylinder to the preſſure of the fluid. The firſt method has been already treated on (Philoſ. Inſtit.) and there will be occaſion to mention it again in the following chapter; the ſecond and third will be for the preſent the objects of conſideration.

160. BENJAMIN ROBINS, an Engliſh Engineer, was the firſt perſon who thought of applying inſtruments to meaſure the initial velocity of a ball of ſmall calibre, near the mouth of the gun. His method conſiſts in firing againſt a pendulum, moveable upon its axis of ſuſpenſion, which deſcribes an arch proportionate to the ſhock of the ball. The exact meaſure of the chord of the arch, the weight of the ball and pendulum, the centre of gravity and oſcillation, and the diſtance from the axis of motion to the point of impact, ſhew the abſolute velocity with which the ball impinged on the pendulum.

FIG. 16. To apply this inſtrument C E for meaſuring the initial velocities of balls from muſquets or wall-pieces; it ſhould be made of iron, and hung at right angles to the axis of ſuſpenſion A B, which muſt be about a foot in length; to D E is ſcrewed a plank of about nine inches ſquare, and of ſuch a thickneſs that the ball cannot penetrate to the iron. For the experiment, the pendulum is ſuſpended (Fig. 17.) from a triangular frame; underneath it, is placed a piece of wood cut in the arch of a circle, of which the circumference is deſcribed from the centre C with a radius greater than C E; and in the plane of the vibrations of the

the pendulum, a ſtylette F is faſtened in E, to trace upon the fine duſt, with which the circumferene G K H is covered, the arch deſcribed by the firſt vibration of the pendulum. Inſtead of the arch of the circle, ROBINS uſed a ribband attached to E, which the motion of the pendulum drew between two iron plates fixed to a wooden bar that was between the legs of the frame, and meaſured the arch deſcribed by the pendulum, by the length of the ribband drawn between the plates.

161. The inſtrument being placed as above directed, if we know;

1. The weight P of all the parts of the pendulum.

2. The diſtance from the point C in the axis of ſuſpenſion or motion to the centre of gravity L, or $CL = a$.

3. The diſtance from C to the centre of oſcillation M, or $CM = d$.

4. The length $CF = b$ of the radius with which the arch G K H is deſcribed.

5. The weight of the ball $= q$.

6. The chord of the arch $= c$ deſcribed by the firſt vibration of the pendulum, and meaſured upon G K H; then the motion communicated to the pendulum, and conſequently the velocity with which the ball impinged on it will be found.

Find the diſtances C L, C M: it is proved, (Philoſ. Inſtit.) that the vis inertiæ of a body moving freely round its axis, is equal to the product of its weight multiplied by the diſtance from the centre of gravity to the axis of motion, and by the diſtance from the centre of oſcillation to the ſame axis; and the quantity of its motion is equal to the product of the vis intertiæ multiplied by the velocity of the pendulum, which is equal to the ſquare root of the verſed ſine of the arch deſcribed by the centre of oſcillation.

Fire a ball againſt the centre of oſcillation M. To find the velocity communicated to this point, make the proportion $b : c :: d : \frac{cd}{b}$, the laſt term is the chord of the arch deſcribed by this point: The verſed ſine of which is $\frac{c^2 d}{2b^2}$, and the uniform velocity of M during one ſecond will be

$$\sqrt{\frac{64 \cdot 36 \cdot c^2 d}{2b^2}}$$

$\sqrt{\frac{64 \cdot 36 \cdot c^2 d}{2 b^2}} = \frac{c}{b}\sqrt{32.18d}$ (Philoſ. Inſtit.) which multiplied by the weight of the pendulum and ball, ſince this does not rebound, i. e. by $Pad + qd^2$, will give $\frac{c}{b} \times \overline{Pad + qd^2} \times \sqrt{32.18d}$ for the quantity of motion. Let $u$ be the uniform velocity with with the ball impinged on the pendulum; as from the moment it entered the pendulum, it followed the direction of its motion, $uqd^2$ will expreſs the quantity of the motion of the ball: thus in a ſtate of equilibrium $uqd^2 = \frac{c}{b} \times \overline{Pad + qd^2}\sqrt{32.18d}$, and $u = \frac{c \times \overline{Pa + qd}\sqrt{32.18d}}{bqd}$ will be the velocity ſought.

162. In the ſecond place, let the ball ſtrike a point D, not in the center of oſcillation: (Fig. 18) then if $f$ expreſs the perpendicular diſtance from the point D to the axis of motion, and $x$ the uniform velocity of this point, the quantity of motion of the point D will be $x \times \overline{Pad + qf^2}$, and if the ball impinged on the pendulum with the velocity $u$, its quantity of motion will be $uqf^2$. Then the equation will be $x \times \overline{Pad + qf^2} = uqf^2$, and $x = \frac{uqf^2}{Pad + qf^2}$. Now as the motion of a pendulum is as great, as if its whole maſs were united to the centre of oſcillation, and as this centre changes whenever the ball impinges on any other point; by expreſſing its diſtance from the axis of motion by the vis inertiæ $Pad + qf^2$ divided by $Pa + qf$, the diſtance of C G from the point G taken as a new centre of oſcillation to the axis of motion will be $CG = \frac{Pad + qf^2}{Pa + qf}$. But the radii C D, C G, are proportional to the velocities of the points D, G, ſince they deſcribe the archs D O, G H in the ſame time; then $CD : CG : f : \frac{Pad + qf^2}{Pa + qf}$ as the velocity of the point $D = x = \frac{uqf^2}{Pad + qf^2}$ is to the velocity of the point $G = \frac{uqf}{Pa + qf} = \sqrt{64 \cdot 36\, GI}$ where G I expreſſes the verſed ſine of the arch G H.

To

To find the velocity $u$ with which the ball impinged on the pendulum, another value of $\sqrt{64.36\,G\,I}$ muſt be ſought: As the chord $= c$ of the arch F G H deſcribed by the ſtylette, and radius C F $= b$ are known, the verſed ſine of this arch will be $\frac{c^2}{2b}$: Then radius C F is to its verſed ſine as radius C G is to its verſed ſine G I or

$$b : \frac{c^2}{2b} :: \frac{Pad + qf^2}{Pa + qf} : \frac{c^2}{2b^2} \times \frac{Pad + qf^2}{Pa + qf};$$

and thus the uniform velocity of the point G will be expreſſed by $\sqrt{\frac{64 \cdot 36\,c^2}{2b^2} \times \frac{Pad + qf^2}{Pa + qf}}$; and on comparing the two expreſſions of theſe velocities

$$\frac{u\,qf}{Pa + qf} = \frac{c}{b}\sqrt{32\,18 \times \frac{Pad + qf^2}{Pa + qf}} \text{ and } u = c\sqrt{32\,18 \times \frac{Pad + qf^2 \times Pa + qf}{b\,q\,f}}$$

the velocity ſought.

163. The weight and length of the pendulum ſhould be ſuch that its vibration may not deſcribe an arch of more than five degrees; and as the balls fired into it increaſe its weight and alter the centres of gravity and oſcillation, the values of $P$, $a$, $d$. ſhould be corrected after each diſcharge.

164. SIG. MATTEI, mathematical inſtrument-maker to the King, has invented a machine for finding with facility the initial velocity of balls meaſured near the mouth of the gun.

FIG. XIX. A B is a horizontal wheel with a vertical axis C D turned by the weight Q, appending to the rope G G and raiſed by the winch N. It may be turned in any other manner, provided that its motion be perfectly uniform and rapid. A E, B F is a circular band of writing paper about 6 inches high, fixed round the circumference of the wheel. The gun for the experiment is immoveably fixed at 20 feet diſtance, and pointed ſo that the axis of the gun produced would paſs through the points H, K, the exact diameter of the wheel. R

is a

is a block of wood placed two or three feet from the wheel to receive the balls; it is of elm, that the penetrations may be uniform.

In uſing this machine it is requiſite to aſcertain when the motion of the wheels is equable, and how time long it takes in each revolution; for this purpoſe various expedients may be deviſed. At TURIN we fitted a little excentric wheel I L to the axis C D, which at each revolution gave a vibratory horizontal motion to a tongue of wood at the extremity of which appended a common pendulum that was ſhortened or lengthened till its vibrations were iſochronous to thoſe of the tongue: the length of the pendulum will ſhew how long the wheel is in making each revolution. So ſoon as the iſochroniſm between the pendulum and the tongue is eſtabliſhed, fire the gun and ſtop the wheel; the two holes made in the rim of paper by the ball, will be eaſily diſtinguiſhed from each other by the edges being turned to the point that the ball went out at. Stretch a thread in the direction M R, paſſing through the centre of the hole H where the ball entered the paper. The diſtance of the other hole K from the point B will be then known: this diſtance ſhews how much one point of the wheel turned, while the ſhot was traverſing the diameter A B.

165. If the mechaniſm and uſe of this machine be well underſtood, it will be eaſy to find the uniform velocity with which the ſhot paſſes through the diameter A B of the wheel, and conſequently its uniform velocity during one ſecond of time. Let D be the diameter of the wheel, $c$ its circumference, $t$ the time that the wheel takes to make one revolution, $m$ the diſtance that a point of the circumference of the wheel turns, while the ſhot is traverſing the diameter; then $m : D :: C : \frac{C D}{m}$, the laſt term will expreſs the ſpace paſſed through by the ſhot with an uniform velocity during one revolution of the wheel: then expreſſing by $u$ the ſpace that the ſhot paſſed through with an uniform velocity in one ſecond, or its initial velocity, $t : 1 :: \frac{C D}{m} : \frac{C D}{t m}$; the laſt term $= u$ will expreſs the velocity ſought. With this machine, when the wheel turns with an equable motion, $t = \frac{4}{5}$ of a ſecond,

D=

$D = 10$ feet, and conſequently $C = \frac{22 \times 10}{7}$; then ſubſtituting theſe values in the expreſſion of the velocity, $\frac{CD}{tm} = u$; if the value of $m$ be the fraction of a foot, the velocity $u$ will be expreſſed in feet. For inſtance, if $m$ be found experimentally $= \frac{1}{4}$ of a foot, then 1571 feet will be the value of $u$.

166. This machine was uſed in making the following experiments which lead to the ſolution of ſeveral very important problems in the theory and practice of artillery.

1. The firſt gun was 5 ft. 6 in. in length of bore, and the weight of leaden bullets was $2\frac{1}{2}$ oz.

2. The ſecond was 5 ft. 10 in. in length of bore, and the weight of bullet $3\frac{1}{2}$ oz.

3. A rifled barrel 3 ft. 5 in. in length of bore, and the weight of bullet $\frac{7}{8}$ oz.

4. Several muſquet barrels of different lengths; the leaden bullets weighing 1 oz.

The powders were thoſe deſcribed in the fortieth paragraph. the wads were of parchment torn in ſeveral places, that they might not damage the rim of paper faſtened round the circumference of the wheel; and lightly compreſſed by the ſame man. During theſe experiments particular attention was paid to moiſture of the atmoſphere, as its variations ſenſibly affect the force of powder (137).

167. The following is a table of initial velocities deduced from experiments with a muſquet 3 ft. 6 in. in length of bore, under three different ſtates of the atmoſphere.

VELOCITY OBSERVED.

| The charge of Powder was 7 drams. | Very moiſt Weather. | Under a mean ſtate of the atmoſphere. | Very dry Weather. |
|---|---|---|---|
| | *Feet.* | *Feet.* | *Feet.* |
| Common War Powder | 1392 | 1542 | 1618 |
| Fine Ditto — | 1569 | 1736 | 1829 |
| Fowling Ditto — | 1566 | 1703 | 1784 |
| Fire-work Ditto — | 1566 | 1706 | 1779 |

Beſide

Beſide the obſervations on the hygrometer it was remarked, that when atmoſphere was very much loaded with vapour, the bore of the gun was ſo moiſt five minutes after the exploſion, that the fixed nitre fell in deliquium; and the tow uſed in cleaning it, was covered with a number of ſaline particles; but on a dry day no moiſture could be perceived after an interval of ſeveral minutes, and the tow came out almoſt unſoiled. It reſults from theſe experiments.

1. That the velocities of ſhot in very dry weather exceed by nearly $\frac{1}{7}$ the velocities, when the atmoſphere is loaded with vapour.

2. That fine war powder produces in muſquets the greateſt effect that can be obtained from a combination of ſaltpetre, ſulphur and charcoal. It is eſſential to add, that with the ſame kind of powder, the velocities were nearly equal in moiſt, heavy weather; under a mean ſtate of the atmoſphere they varied about $1\frac{1}{2}$ in the 100; and in very dry weather, their difference amounted to 4 in the 100.

168. The following experiments made with guns of different lengths and calibres, under a mean ſtate of the atmoſphere are a proof that fine war powder is the ſtrongeſt.

| Nature of Guns. | Kind of Powder. | Weight of Powder. | | Initial velocity. |
|---|---|---|---|---|
| | | *Drachms.* | | *Feet.* |
| A Muſquet 1ft. 10 in. length of bore. | Fine War Powder | 7 | — | 1390 |
| | Fowling Ditto | 7 | — | 1367 |
| | Fire-work Ditto | 7 | — | 1372 |
| Rifled Carabine | Fine War Powder | 7 | — | 1956 |
| | Fowling Ditto | 7 | — | 1920 |
| | Fire-work Ditto | 7 | — | 1934 |
| A Wall-piece carrying a leaden bullet, in weight $2\frac{1}{2}$ oz. | Fine War Powder | 20 | — | 1956 |
| | Fowling Ditto | 20 | — | 1928 |
| | Fire-work Ditto | 20 | — | 1923 |
| A Muſquet 3 ft. 6in. in length of bore. | Fine War Ditto | 7 | — | 1736 |

The experiments with a mortar made by Major RONZINI in the month of Auguſt 1761, likewiſe prove the excellence of fine war powder. The proportions of the mortar were very exact; it was laid at 45°, fixed in an iron bed weighing 616 lb. and projected an iron ſhot 27 lb. in weight, the chamber

chamber contained one ounce of powder, the ſame charge was uſed each time without a wad, that there might be the leaſt difference poſſible. The following table ſhews the reſult.—

| Kind of Powder. | | Length of Range *Yards.* |
|---|---|---|
| Muſquet Powder | — | 249 |
| Fine War Ditto | — | 298 |
| Fowling Ditto | — | 294 |
| Fire-work Ditto | — | 296 |

169. To aſcertain the effect that a difference in the weight of ſhot and windage have on the velocity, three bullets were fired from a wall-piece, and two from the muſquet 3 ft. 6 in. in length of bore. The firſt bullet with which the wall-piece was loaded weighed $3\frac{1}{4}$ oz. the ſecond weighed 3 oz. the third was equal in diameter to the firſt, but equal in weight to the ſecond, a ſmall pebble having been put into the centre when it was caſt.

The muſquet bullets were 1 oz. and $\frac{7}{8}$ oz. in weight: in order to have a third kind, cartridges like thoſe uſed by the Infantry, which drop without ramming to the bottom of the barrel when the muſquet is clean, were made with carabine balls.

The wall-piece was charged each time with 23 drachms, and the muſquet with 7 drachms of fine war powder. The experiments were made under a mean ſtate of the atmoſphere, and the following table ſhews the reſult.

| | Balls. | | Initial Velocities, *Feet.* |
|---|---|---|---|
| Wall-piece | Firſt kind | — | 1770 |
| | Second ditto | — | 1855 |
| | Third ditto | — | 2068 |
| Muſquet. | Firſt ditto | — | 1736 |
| | Second ditto | — | 1834 |
| | Third ditto | — | 1863 |

In theſe two caſes, the initial velocities of the ſhot of the ſecond kind exceed thoſe of the firſt, though a greater quantity of the fluid muſt neceſſarily have eſcaped owing to the windage; and the ſhot of the third kind from their greater

diameter and leſs weight have a ſtill greater initial velocity.

170. The following experiments made under a mean ſtate of the atmoſphere, ſhew the initial velocities of ſhot impelled by different charges of fine war powder.

| | Weight of Powder. *Drachms.* | | Initial Velocities. *Feet.* |
|---|---|---|---|
| Muſquet, length of bore 3 ft. 6 in. | 5 | — | 1399 |
| | 7 | — | 1736 |
| | 10 | — | 1984 |
| Wall-piece, weight of bullet 2½ oz. | 11½ | — | 1504 |
| | 18 | — | 2056 |
| | 25 | — | 2060 |

A muſquet fired with the ordinary charge of 7 drachms of powder does not range ſo far, as if the charge were larger; but as the barrel would ſoon become too hot, the ſmaller charge is preferred. From the experiments made with the muſquet (167, 168, 169,) it will be eaſy to deduce by analogy, the velocities of other fire-arms diſcharged in very moiſt or very dry weather. For example, to know the initial velocity of a ſhot from a wall-piece fired in very dry weather, with a charge of 25 drachms of fine war powder: as its initial velocity under a mean ſtate of the atmoſphere is 2060 feet, and that of the muſquet 1736 feet; and the initial velocity of the ſame muſquet in very dry weather is 1829 feet, by making a proportion of theſe values 1736 : 2060 :: 1829 : 2245 feet, which is the velocity of the wall-piece in very dry weather.

171. Since the initial velocity of fire-arms of all lengths may be thus found, it will be eaſy to aſcertain the ſcale of preſſures which the elaſtic fluid exerts upon the ſhot in different points of the bore of the gun. For this purpoſe, fire three or four guns differing in length but equal in calibre, charged with the ſame quantities of powder: having meaſured the initial velocities of the ſhot, ſet off from A to R (Fig. 20.) on the line A R the lengths of the guns taken from the part of the cylinder where the ſhot is lodged to the mouth of the piece; and ſuppoſing A C to be the length of the ſhorteſt gun; A D that of the ſecond, and A B that of the longeſt; make the perpendiculars C E, D F, B G equal to the initial velocities of the reſpective ſhot; then a line paſſing through the points A, E, F, G will be the ſcale of velocities in the ſpaces A C, A D

A D, A B, which the ſhot has paſſed through with an accelerated motion. The equation of this ſcale may be found in the manner laid down in the preceding chapter for finding the correſponding ſcales S M N O of the preſſures of the fluid.

172. To obtain the initial velocities, four muſquets of different lengths, carrying a 1 oz. ball, were fired with 7 drachms of fine war powder (166), under a mean ſtate of the atmoſphere.

| Length of Barrel from the Ball to the Muzzle. | | | Initial Velocities. |
|---|---|---|---|
| *Feet.* | *Inches.* | | *Feet.* |
| 0 | 11 | — | 1037 |
| 1 | 10 | — | 1390 |
| 3 | 8 | — | 1736 |
| 4 | 8 | — | 1815 |

FIG. 20. Then conſtructing a figure according to the directions given in the preceding paragraph, and examining the proportion that the ordinates bear to the abſciſſas; the ſcale A E, F G of the velocities is an ellipſis whoſe ſemi-conjugate axis A R is 4 feet 8 inches, and ſemi-tranſverſe axis R H about 1815 feet. Hence it reſults;

1. That the ſcale of preſſures S M N O is in this caſe a right line, which when produced cuts the line of direction in the centre R of the ellipſis.

2. That the initial velocities of guns fired under the preceding circumſtance, are not increaſed by making the barrels longer than A R.

To give a theorem for finding the initial velocities of muſquets ſhorter than A R, fired horizontally with 7 drachms of war powder, under a mean ſtate of the atmoſphere, it muſt be remembered that as the ſum of the preſſures $A R S = \overline{R H}^2$, then $\frac{A S}{2} = 690312$ feet.

Now let A D be the length of any gun; then the ſuperficies of the rectilinear trapezium A D N S which expreſſes the ſum of the preſſures will be $\frac{A S \times \overline{A R^2 - D R^2}.}{2 A R}$, but the ini-

tial velocity D F correſponding with this trapezium is expreſſed by the ſquare root of the ſame ſuperficies:

For example, Let A D be $\frac{1}{6}$ of a foot, D R will be 4 feet 6 inches or $\frac{27}{6}$, which ſubſtituted in the theorem, will give $D F = u = \sqrt{1479\ 26 \times \frac{784}{36} - \frac{729}{36}} = \sqrt{1479\ 26 \times \frac{55}{36}} =$ 475 feet for the initial velocity.

173. This method of finding the ſcale of velocities in the ſpaces, may be practiſed when the wad is ſtrongly rammed on the powder; for then the greateſt ordinate of the correſponding ſcale of preſſures is at, or very near to the place occupied by the ſhot, in the bore of the gun: and there is no difficulty in reducing by approximation the line of the velocities to a regular curve, from which, expreſſed geometrically may be deduced the ſcale of preſſures. But when the greateſt ordinate is diſtant from the part occupied by the ſhot, as with weak powder or low wads; then to find the curve line of velocities, it is not only neceſſary to make experiments with the guns mentioned in the preceding paragraph, but with others in which the ſhot has a very ſmall ſpace to paſs through, as 2 or 3 calibres: thus the curve line may be deſcribed from its origin, and any irregularity corrected by approximation.

174. If the ſcale of preſſure only be ſought; as the velocities are in the ſub-duplicate ratio of the ſum of the preſſures, whenever the proportion of two velocities C E, D F is leſs than the ſub-duplicate ratio of the ſpaces A C, A D, or of the length of the part of the bore from the ſhot to the muzzle, then the correſponding part S M N of the ſcale of preſſures will converge towards the mouth of the gun: when the ratio of the velocities is equal to the ſub-duplicate ratio of the correſponding lengths, the ſcale S M N will be parallel to the directrix A D; and when greater, it will diverge from it.

175. Having aſcertained the initial velocity $= u$ and the ſcale of preſſures, the value of $n$, which expreſſes how much the greateſt elaſticity of the fluid acting on the ſhot exceeds the elaſticity of the atmoſpheric air, may be found by means of

of the theorem $u=\sqrt{\frac{96.54npl\,A}{2r}}$ where A expreſſes the height of a barometer made of the ſame metal as the ſhot; $l$ the length of the fire-arm meaſured from the ſhot to the mouth of the piece; $p$ the ratio between the area A S N D and the rectangle A S × A D; and $r$ the radius of the ſhot. For example, take a muſquet (172) 3 ft. 8 in. in length of bore $=l$; as in this caſe A = 2 ft. 10·84 in. $r=$ ·243 in.; and $u=1736$ feet; ſuppoſe $p=\frac{19}{30}$: then by ſubſtituting theſe values in the theorem, $1736=\sqrt{\frac{96\cdot54\times3.8\times2.10\cdot84\times\frac{19}{30}n}{\cdot587}}$; whence $n=$ nearly 280 times the mean elaſticity of the atmoſphere.

176. The initial velocity of cannon balls may be eaſily found by this method of determining the velocities of bullets projected from fire-arms of ſmall calibre: not only the charge that gives the longeſt range, and the law of preſſure of the fluid on the ſhot in paſſing along the bore may be aſcertained; but the greateſt elaſticity of the fluid, and the point in the length of the bore where it is produced, may be determined: in a word, all the ſolutions of the problems relative to ſmall pieces from the 167 paragraph to the preſent, are equally applicable to the largeſt cannon.

To determine the initial velocity of cannon balls, there muſt be a large homogeneous butt: if neceſſary, one muſt be made of earth, cleared of ſtones, ſifted and well rammed. The guns muſt be placed near the butt, and at ſuch a diſtance from each other, that the looſening of the earth from the penetration of one ſhot may not facilitate the entrance of the other. The depth of their reſpective penetrations muſt be meaſured, and the values ſubſtituted in the place of S in the theorem $S=g\,D\,u^2$, where D expreſſes the diameter of the ſhot, $g$ its ſpecific gravity, and $u$ its velocity, then $u=\sqrt{\frac{S}{gD}}$ which is a known quantity.

Let a wall-piece, whoſe initial velocity is known, be fired againſt the ſame butt; meaſure the penetration of the

ſhot, and ſubſtitute it in the place of S in the theorem $u=\sqrt{\frac{S}{gD}}$: In the room of $g$ and D inſert their known values, which will give the relative value of $u$: then by analogy, the relative velocity of the bullet is to its initial velocity, as the relative velocity of the cannon ſhot is to its initial velocity. Suppoſe, for example, that the leaden bullet fired from the wall-piece be 1 inch in diameter = D and that its penetration S = 4 feet; as the ſpecific gravity of lead is $g=9060$ then $u=\sqrt{\frac{S}{gD}}=\sqrt{\frac{48}{9060}}$. Suppoſe again, that the cannon ſhot be 6 inches in diameter = D and its penetration into the butt 14 feet = S, as the ſpecific gravity of iron is 6115; $u=\sqrt{\frac{S}{gD}}=\sqrt{\frac{28}{6115}}$. Then if the known initial velocity of the bullet fired from the wall-piece be 2023 feet, $\sqrt{\frac{48}{9060}}:\sqrt{\frac{28}{6115}}::2023:1880$ feet, which will be the value of the velocity ſought.

This theorem will ſerve to reſolve other problems; for inſtance, by knowing the diameter, denſity, velocity and penetration of one ſhot, the penetration of the other ſhot differing in denſity, velocity and diameter into the ſame butt may be found.

177. From a ſeries of experiments made according to the foregoing principles, under a mean ſtate of the atmoſphere with guns, (89) charged with a quantity of common cannon powder, equal to about $\frac{1}{8}$ of the weight of the ſhot in 32 and 16 prs; and to $\frac{1}{4}$ its weight in 8 and 4 prs: it reſults that 1349 feet will be the mean initial velocity of 32 prs; 1433 of 16 prs; more than 1517 of 8 prs; and leſs than 1517 of 4 prs.

Lieut. DE BUTET invented in 1764 a very ſimple machine for meaſuring the initial velocity of projectiles. He applies a little plate of metal provided with a moveable index to any wheel that turns with an equable motion, and ſufficient velocity; the index is held at ſome diſtance from the circumference of the wheel, by a thread that is ſtretched acroſs the mouth of the gun. When the gun is fired, the ſhot breaks the thread, and ſets at liberty a ſpring, which inſtantly

inſtantly preſſes the index againſt the wheel, upon which it deſcribes an arch, till it is checked by the impact of the ſhot againſt a moveable butt, placed at the diſtance of a few feet: to this effect one extremity of a rod is faſtened to the butt, and the other to the plate; thus the index is drawn back by the rod, which follows the movement of the butt, and ceaſes to deſcribe the arch on the circumference of the wheel.

The motion of the wheel, the diſtance from the muzzle of the gun to the butt, and the arch deſcribed by the index being known, it is eaſy to aſcertain the ſpace that the ſhot paſſes through in one ſecond of time with an uniform velocity; or in other words, its initial velocity. To diminiſh the friction as much as poſſible, a ſmall groove is made in the part of the wheel that receives the index, and filled with greaſe, which preſents a very ſlight reſiſtance. By means of this inſtrument the time of the ſhot's paſſage along the bore of the gun, the initial velocity of ſhells, and the reſiſtance of the air to their motion may be determined; if allowance be made for the modifications that muſt enſue.

178. In aſcertaining the initial velocity of ſhot projected from fire-arms of cylindric bore in the third method (159); it muſt be remarked, that ſo ſoon that the ſhot begins to move, it continually acquires freſh velocity as it advances from E to G (Fig 13), and loſing a part of the preſſure of the fluid is only impelled by the exceſs of the velocity of the fluid over its own velocity: this diminiſhes as the ſhot approaches the muzzle; the action of preſſure againſt the ſhot would be totally loſt if the gun were very long, but it would continue againſt the ſides of the gun. Whence it reſults, that the ordinates H Y, G Z of the ſcale X Y Z of the preſſures of the fluid againſt the ſhot, which commences at the ſame point X as the ſcale X N O of the preſſures againſt the ſides of the gun, are ſhorter than the correſponding ones H N, G O, and their differences N Y, O Z become greater as the ſhot approaches G. Thus, when the ſeveral points of the cylinder are proportioned to the different preſſures of the charge, there are always two ſcales; one, expreſſing the preſſure of the fluid againſt the ſides of the gun in each of the phyſical points of its length; the other expreſſing the preſſures againſt the ſhot in the ſame points. When the firſt of theſe ſcales is continually converging towards the mouth of the piece, its figure is determined by the length of the gun;

and it may be conſidered as the limit of the greateſt velocity of the ſhot.

179. In fire-arms of all calibres fired with large charges and wadded, ſo that only the neceſſary interſtices for the propagation of fire remain between the grains, the thickneſs of metal muſt be increaſed gradually from the muzzle to the breech, that the gun may be enabled in every point to reſiſt the actual preſſure of the elaſtic fluid: wherefore the ſcale of preſſures againſt the ſides converges toward the mouth of the gun, and the greateſt ordinate of the ſcale is very near the place occupied by the ſhot. Then,

FIG. XV. In order to find the equation of the ſcale of preſſures, draw the right line K I parallel to the directrix E G, conſidered as the axis to which the ordinates are perpendicular: let the preſſure K E $= p$ and the abſciſſa E L $=$ K I $= x$. As the ordinate I H of the ſegment K H $y$ appertains to the abſciſſa K I, I H may be expreſſed by $nx$, and multiplying $nx$ by the abſciſſa, $= x$ and by $m$ denoting the fraction that ſquares the ſurface K I H the product $nmx^2$ will expreſs the ſurface K I H: now the rectangle E K I L $= px$, therefore the ſuperficies E K H L $= px - nmx^2$; and call the velocity I B that anſwers to this ſuperficies V, then $V = \sqrt{px - mnx^2}$.

180. Since muſquet barrels were firſt made in PIEDMONT, none have been received at the Arſenal before they had been proved in the preſence of ſome officers of artillery. More than a hundred thouſand barrels have been proved in the following manner: they are charged with 17 drachms of common cannon powder; over which is put a very high wad of hard tow, that is with difficulty preſſed into the barrel, and is afterwards rammed down with all the force that the armourer can exert: a leaden bullet weighing 18¼ drachms is then put in and wadded as before. The barrels thus loaded, are placed horizontally with the breech againſt a ſtrong beam of wood, and each of them is fired twice. At every proof ſome of the barrels have burſt, and the crack is ſometimes at the breech, at other times at the middle of the bore, or near the muzzle: but as it is not found to have happened more frequently in one part than another, the officers and manufacturers have deemed it unneceſſary to make any alteration in the thickneſſes of metal; ſo that they may be reaſonably regarded as proportionate to the preſſures of the elaſtic fluid

fluid generated during the proof, allowing for the proportion that eſcapes by the vent, and the windage. Thus the ſhape of a gun being known, the limits of the greateſt velocity of the ball in each point of the length of the bore may be found (179).

181. The thickneſs of metal in each point of the length of the cylinder is determined by a (Fig. 21) right line F D, drawn from the breech to the muzzle obliquely to the axis; thus the lengths B E, B H, and the correſponding thickneſſes E F, H L of a gun A C B D being known, the inclination of the right line M O N which is the ſcale of the preſſures of the fluid againſt the ſides of the gun may be determined, the ordinates E M, H O, B N, being in the ratio of the correſponding thickneſſes E F, H L, B D. If the right lines E B, F D be produced, they will meet at the point R, where the line M O N will always terminate, even when F L D and M O N are curves. Thus E R $= b$ will be known and conſidering $p =$ E M, the value of $n$ will be $\frac{p}{b}$: then $\varphi o = \frac{px}{b} = nx$ and $m = \frac{1}{2}$ ſince M $\varphi$ O is a triangle. Hence $nmx^2 = \frac{px^2}{2b}$ and conſequently $V = \sqrt{px - nmx^2} = \sqrt{px - \frac{px^2}{2b}}$ which is an equation to the ellipſis to be conſtructed in the manner already pointed out (172).

Take $p = 2b$, then $V = \sqrt{2bx - x^2}$ is an equation to a circle whoſe radius $= b$; from the point R taken as centre with a radius R E $= b$ deſcribe the arch E G K, then the ordinates H G, B K, will expreſs the relative velocities which the bullet would have at the points H, B, if the line M O N were the ſcale of preſſures of the fluid. It ſhould be remarked;

1. That on diminiſhing the charge of powder in theſe barrels without weakening the reſiſtance of the ſhot and wads, the preſſure of the fluid at the point E will remain the ſame, but it will be weaker at the points H and B, (152); the velocity therefore of the bullet at the ſame points will be leſs.

2. That on diminiſhing both the charge and the reſiſtance, either by uſing ſmaller wads or by ramming them down with leſs force, the preſſure of the fluid will be leſs at the point E, as well as at H and B.

3. That

3. That on altering the reſiſtance, the ratio of the preſſures will vary alſo. Theſe conſequences are deducible from the preceding theory, and are confirmed by experience.

182. By the theorem $V=\sqrt{2bx-x^2}$ it may be aſcertained with tolerable accuracy, how much the length of the gun affects the range. Take, for example, the gun A D P, (Fig. 21) in which the thickneſſes from E to the muzzle, proportionate to the largeſt charges; are determined by a right line. To find the difference between the velocities of the ſhot; or in other words, the length of the ranges, by firing a ſhorter gun as A H, or a longer one as A Q with the ſame charge as A D P, the right lines E B, F D muſt be produced till they meet in the point R, and from R taken as centre with the radius R E, deſcribe an arch E G K: draw to A R the normals H G, B K, Q T, which will expreſs the ratios of the length of the ranges, correſponding to the lengths of the gun. It was obſerved that this theorem would only give an approximation; in fact the line M O N being the ſcale of preſſures againſt the ſides of the gun; M Y Z which is the ſcale of preſſures againſt the ſhot, ſooner falls on E R, which it cuts in the point S. Thus the true ſcale of velocities is E I V X in which the difference between the velocities at the points H, B, Q is leſs than in the other ſcale E G K. But whatever be the nature of the line M Y Z, it muſt neceſſarily when produced cut the right line R E in ſome point S; for as the fluid expands in a ſpace which is continually enlarging, and partly eſcapes by the vent and windage, its velocity will be at length ſo much diminiſhed, that it will no longer impel the ſhot. The point S is always the centre of a re-entering curve line E I V X, of which S E is the ſemi-axis, and E M the parameter; and by it may in all caſes be determined the greateſt length that ought to be given to cylindric fire-arms, ſince beyond this point the ſhot receives no increaſe of velocity. From theſe premiſes may be likewiſe inferred, that in the ſame gun the point S will be more or leſs diſtant from A, in proportion to the quantity and quality of the powder, and to the windage and denſity of the ſhot.

183. Since the radius $\frac{BP}{2}=r$ and the thickneſs of metal $EF=m$ are known, and its tenacity may be determined

mined by experiment, the elaſticity $=n$ of the fluid may be found by the means of the theorem $9962\,nr=mq$; and by ſubſtituting in the theorem $V=\sqrt{\frac{96.54npl\mathrm{A}}{2r}}$ the values of $n$, $r$, $l$, $=$ E B, A $=$ the height of a barometer made of the ſame metal as the ſhot, and $p$ the ratio between the trapezium E M N B and the rectangle E M $\times$ E B, the value of the initial velocity $=$ V of the ſhot will be likewiſe found.

FIG. 21. For example, ſuppoſe D A P to be a wall-piece, whoſe thickneſſes of metal are in equilibrio with a given charge; let the diameter D P $=2r=2$ inches, E F the greateſt thickneſs of metal in the place where the ſhot is lodged $=m=2$ inches, and the tenacity of metal $=4723200=q$; by ſubſtituting theſe data in the theorem $9962\,nr=mq$, $n9962\times\frac{1}{12}=\frac{1}{6}\times 4723200$: the greateſt elaſticity of the fluid $=n$ is therefore nearly equal to 800 times the mean preſſure of the atmoſphere.

To find the initial velocity of a leaden bullet fired from this wall-piece let E B $=l=3\frac{1}{2}$ feet, and $p=\frac{2}{3}$; A will be about 3 feet; then ſubſtituting theſe values in the theorem $V=\sqrt{\frac{96.54npl\mathrm{A}}{2r}}$ it will give $V=\sqrt{\frac{96.54\times 800\times\frac{2}{3}\times 3\frac{1}{2}\times 3}{\frac{1}{6}}}$ $=1800$ for the initial velocity of the leaden bullet.

But if an iron ſhot be fired from it, A will be equal to $4\frac{1}{2}$ feet, and the initial velocity will be

$$V=\sqrt{\frac{96.54\times 800\times\frac{2}{3}\times 4\frac{1}{2}\times 3}{\frac{1}{6}}}=2043.$$

CHAP.

## CHAP. V.

### Of Experiments for Ascertaining the Resistance of the Air to Bodies projected from Fire-arms.

184. THE initial velocities of ſhot projected on a horizontal plane from guns, equal in length, but differing in calibre, fired with charges proportioned to the weight of the ſhot, with powder of the ſame quality and wads equally well rammed, are greater in proportion, as the calibre of the piece is leſs. But if the ſame gun be fired on an inclined plane, the difference between the ranges will diminiſh in proportion to the inclination and extent of the plane, till at length the guns of large will range farther than thoſe of ſmaller calibre.

185. From the longer range of guns of ſmall calibre, it may be inferred that the ratio of the ſum of the preſſures to the diameter of their ſhot, is greater than in guns of larger calibre. When the reſiſtance to the exploſion conſiſts only of the weight of the ſhot and wads, the preſſures muſt be proportionate to the diameter of the ſhot, and of courſe, greater in guns of large calibre; but in the preſent caſe, the reſiſtance ariſes principally from the friction which muſt neceſſarily be greater in the ſmaller guns, ſince they are both equally rammed: from the ſame cauſe alſo the powder being more compact in the ſmall guns, the exploſion takes place more inſtantaneouſly, wherefore the ratio of the ſum of the preſſures to the diameter of the ſhot muſt be greater: the ſhot likewiſe in paſſing through a greater length of bore in the guns of ſmall calibre, will be impelled by the fluid for a longer ſpace of time, whence its velocity muſt be increaſed.

186. The ſecond effect (184) proceeds ſolely from the reſiſtance of the air to the motion of the projectile: this reſiſtance is very conſiderable when projectiles move with great velocity, and is the greater as the diameter of the ſhot is leſs.

The following is a reſult of experiments made in June 1764, on the Banks of the Po, and a compariſon between the actual and potential ranges. The charges were ſuch as would give the velocities marked in the table, and the

the guns were laid with every neceſſary precaution. The medium of ſeveral rounds was taken, and the direction was along that part of the Po, which runs almoſt in a right line from the mills of *Rocca-Franca* to the *Chapel of the Crucifix.*

Compariſon between the actual ranges of ſhot meaſured in June 1764, along the Banks of the Po, and thoſe which a given initial velocity would produce, if there were no reſiſtance in the air to the motion of the ſhot.

| | Initial Velo. | Elevation. | Ranges. Experimented. | Ranges. Potential. |
|---|---|---|---|---|
| | Feet. | | Yds. | Yds. |
| Rifled Carabines bullets weighing $\frac{1}{4}$ of an ounce. | 1956 | 15° | 902 | 19903 |
| | | 24° 20″ | 938 | 29854 |
| | | 45° | 895 | 39806 |
| Muſquet, weight of bullet 1 oz. | 1736 | 7° 15″ | 948 | 7845 |
| | | 15° | 1305 | 15691 |
| | | 24° 20″ | 1335 | 23537 |
| | | 45° | 1181 | 31383 |
| Wall-pieces. Balls weighing 3 oz. | 1855 | 15° | 1433 | 17897 |
| | | 24° 20″ | 1753 | 26734 |
| | | 45° | 1629 | 35794 |
| Balls weighing 3 $\frac{1}{2}$ oz. | 1770 | 15° | 1699 | 16307 |
| Balls weighing 3 oz. but equal in diameter to 3$\frac{1}{2}$ oz. balls. | 2068 | 15° | 1630 | 22268 |

*N. B.* During the five mornings that theſe experiments were carrying on, the barometer at the battery was ſtationary at 29 inches, except towards the end of the third morning when it roſe a little.

This compariſon ſhews that the rifled carabine with an initial velocity of 1956 feet only ranged 895 yards, at the elevation of 45°; while that from the theory of projectiles moving in vacuo, it ſhould have ranged 39806. Now as the only difference between the range calculated from the initial velocity meaſured near the mouth of the piece, and the actual range at the elevation of 45°, is in the ſpace paſſed through by the ſhot; it muſt be owing to the maſs of air diſplaced by it, and conſequently to the reſiſtance that the air oppoſes to its motion.

187. The

187. The following experiment proves that the reſiſtance of the air to a projectile, is greater in paſſing over water than land. In June 1764, ſeveral rounds were fired from the mill of *Rocca Franca* over the Po, from a wall-piece carrying a $3\frac{1}{8}$ oz. bullet, at the elevation of 15°, with a charge that gave an initial velocity of 1770 feet; the mean range taken with the greateſt accuracy was 1799 yards, the ſame gun was afterwards fired in the ſame manner along the road leading to *Stupinigi*, and the mean range was 1863 yards.

188. From the preceding compariſon are deduced ſome of the corollaries in the theory of the air's reſiſtance (Philoſ. Inſtit.)

1. That the air's reſiſtance is greater in ſhot of ſmall than of large diameter, provided the ſpecific gravity be the ſame.

2. That in ſhot of equal diameters the moſt denſe ranges the fartheſt.

3. That when the gun and butt are in the ſame plane, the elevation that will give the longeſt range with a given charge is leſs than 45°.

4. That the leſs the diameter and denſity of the ſhot, the more the elevation that gives the longeſt range, is under 45°.

5. That the longeſt range to be obtained with the largeſt charge, depends on the direction of the gun, the initial velocity of the ſhot, its diameter and weight, the denſity of the air, and the equality or difference between the planes of the gun and butt. Hence, (102, 103, 104,) in meaſuring the ranges to aſcertain the charges that will impel the ſhot with the greateſt velocity, the reſults are liable to ſuch modifications, particularly when the firſt graze of the ſhot is at a diſtance from the gun, that it requires a ſeries of experiments, before any one point can be accurately determined.

189. In this compariſon between the actual and potential ranges, it was ſuppoſed that the charge that gives a certain initial velocity when the gun is laid horizontally, would give the ſame at different degrees of elevation. To prove that this ſuppoſition is true with regard to ſhot of ſmall diameter, a muſquet (169) was directed againſt a block of wood equally porous, placed at the diſtance of 5 feet, it was fired horizontally with a charge that gave an initial velocity of 1736 feet: it was again loaded in the ſame manner, and fired in a vertical

tical direction againſt the ſame block placed at an equal diſtance, the ſhot each time penetrated to the depth of 12 inches.

190. Since the initial velocity of ſhot of ſmall diameter, is the ſame whatever be the elevation of the gun, it follows that the increaſe of the elaſtic fluid produced when the piece is at the higheſt elevation, is in the increaſe of reſiſtance ariſing from the elevation, in the ſame ratio as theſe two forces are, when the piece is fired horizontally.

191. Let A E be a horizontal line making with the lines A F, A G, A H, A K the ſame (Fig. 22) angles as the guns were fired under in the preceding experiments: ſet off the lengths A B, A C, A D, A E of the correſponding ranges, and erect the perpendiculars B F, C K, D G, E H; the lines A F, A G, A H, A K, will expreſs the ſpaces that the ſhot paſſed through by the impulſion of the elaſtic fluid, and the perpendiculars B F, C K, D G, E H the ſpaces paſſed through by the power of gravity. Thus it will be eaſy to lay down the curve that the ſhot deſcribed in its flight, either geometrically or by *Dulac's* inſtrument.

192. A line drawn through the points A, F, G, H, K, will be a curved line of projections, and will ſhew the point where the ſhot will ſtrike the horizontal line A E when the elevation is leſs than 45°: on the contrary, if the point of the line A E which it ought to ſtrike be given, the proper degree of elevation may be found without tracing the curve deſcribed by the ſhot in its flight. If the guns in June, 1764 had been elevated above 45°, in order to know the correſponding length A N of the ranges, the curve A F G H K M L of projections would have been complete.

193. This method of finding the curve deſcribed by projectiles, may be uſed when the initial velocity remains the ſame, though the elevation be altered; but when both the velocities and elevations are different, the following method may be adopted. (Fig. 23) Chuſe a piece of ground on which the guns may be placed at the different heights A, C, D; fire ſome rounds from A, charging and laying the piece always in the ſame manner; which in the preſent caſe will be ſuppoſed to be horizontally, and mark at each diſcharge the firſt graze of the ſhot: then fire from C, D, E with exactly the ſame direction, elevation, and charge, and mark the firſt grazes L, B, Q. Erect the perpendiculars I H, L K, B M, Q F which will be the abſciſſas of the curve deſcribed

deſcribed by the ſhot, and the horizontal lines A H, C K, D M, E F will be correſponding ordinates; then from the value of theſe lines the nature of the curve may be deduced, or traced mechanically; and will be moſt applicable to thoſe elevations where the initial velocity remains nearly the ſame. If the ground at the points I, L, B, Q be ſuch that the ſhot can penetrate in the ſame direction with which it impinges, the holes being the tangents of the curves, the ſub-tangents and ſub-normals that correſpond with theſe points may be likewiſe known. Thus an equation to the curve may be found by the inverſe method of tangents.

194. The curve thus found may be reſolved into the ſimple movements of which it is compounded, by knowing the time that the ſhot is paſſing from the mouth of the piece placed ſucceſſively in A, C, D, E, to the points I, B, L, Q, where it touches the ground; for this purpoſe, a common pendulum or watch that marks very ſmall diviſions of time as $\frac{1}{2}$ or $\frac{1}{3}$ of a ſecond will anſwer. Place it near the men who are ſtationed to obſerve the firſt grazes, and let them begin to reckon the inſtant they perceive the flaſh of the gun. Suppoſe that the (Fig. 24.) time of the ſhots flight from A to $I = a$ from C to $L = b$, from D to $B = d$, and from E to $Q = f$; mark on the line A E, the times $AB = a$, $AC = b$, $AD = d$, $AE = f$, and make the ordinates B H, C I, D K, E L, equal to the ſpaces that the ſhot acted on by the impelling power has paſſed through in the correſponding times (193); A H I K L will then be the ſcale of ſpaces paſſed through in theſe times, from which may be deduced the ſcale of initial velocities; and again from this laſt, the ſcale of momentaneous reſiſtances of the air to the motion of the ſhot.

FIG. XXV. Mark in the ſame manner on the directrix M V, the times $MR = a$, $MT = b$, $MS = d$, $MV = f$ and erect the ordinates R $r$, T $t$, S $s$, V $u$, each equal to the ſpaces that the ſhot has paſſed through by the power of gravity (193.); M $r$ $t$ $s$ $u$ will then be the ſcale of velocities, and give the ſcale of momentaneous reſiſtances oppoſed by the air to the movement of gravitation.

195. If the law of the air's reſiſtance only be required, one of the following methods may be uſed, and will give reſults more accurate than any of the former ones (186, 193, 194.): the firſt conſiſts in finding the ſcale of ſpaces that the ſhot

ſhot acted on by the impelling power has paſſed through in correſponding times. The ſecond is to find by means of this movement of impulſion, the ſcale of retarded velocities in correſponding ſpaces. To find the firſt ſcale, fire ſome (Fig. 26.) rounds from the point S, in the direction S $r$ with equal charges, againſt a butt placed at the ſeveral diſtances S $o$, S $l$, S $m$, S $n$. Now as two points on the ſurface of this butt will be always known, viz. the point where the line of direction S $r$ falls, and that which the ſhot ſtrikes, the ſpaces $o\,a$, $l\,b$, $m\,c$, $n\,d$, paſſed through by the gravitating principle, and the correſponding ſpaces $s\,o$, $s\,l$, $s\,m$, $s\,n$ paſſed through in the ſame time by the movement of impulſion will be known, and the curve S $a\,b\,c\,d$ deſcribed by the projectile will be found. If the butt be placed at ſuch a diſtance that the longeſt line $n\,d$ of deſcent does not exceed 150 feet; the reſiſtance of the air to the movement of gravitation will be inconſiderable, and the theorem $S = \frac{32.18t^2}{2}$ will ſerve to determine the time $= t$, that the ſhot is paſſing through the ſpaces $o\,a$, $l\,b$, $m\,c$, $n\,d$ in its movement of gravity; and alſo through the ſpaces S $o$, S $l$, S $m$, S $n$ in its movement of impulſion.

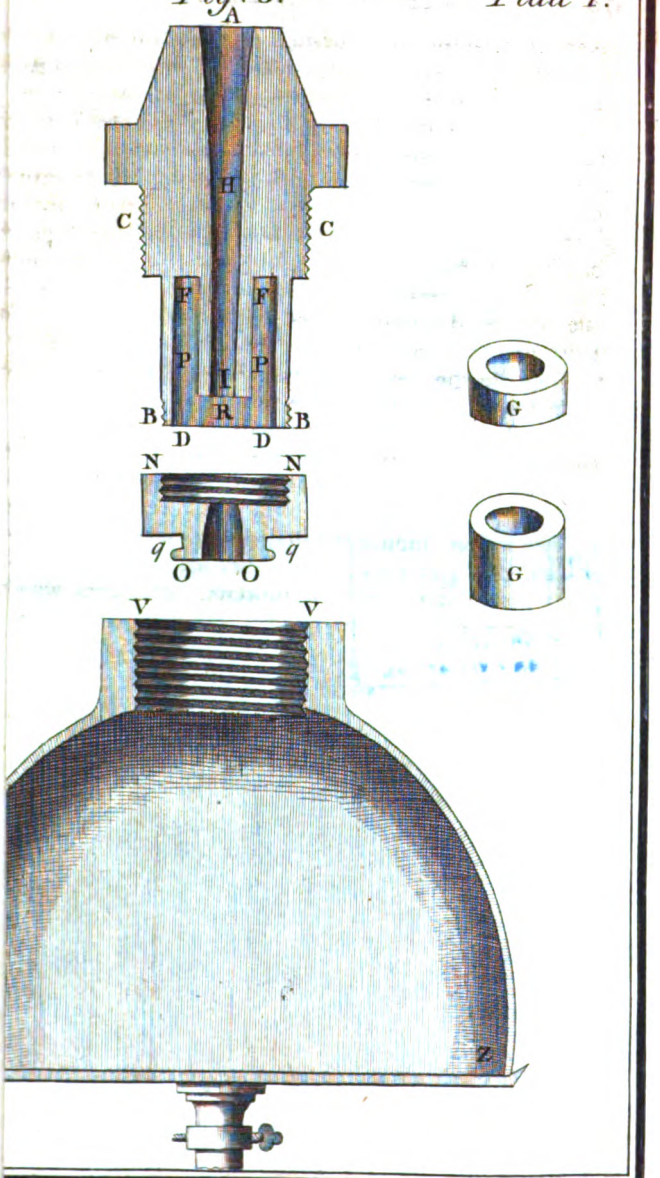
FIG. XXIV. Draw the directrix A E, making A B $= \sqrt{\frac{2}{32.18}}\,o\,a$, A C $= \sqrt{\frac{2}{32.18}}\,l\,b$, A D $= \sqrt{\frac{2}{32.18}}\,m\,c$, A E $= \sqrt{\frac{2}{32.18}}\,n\,d$, and erect at the points B, C, D, E, the perpendiculars B H $=$ S $o$, C I $=$ S $l$, D K $=$ S $m$, E L $=$ S $n$; then a line paſſing through the points A, H, I, K, L, will be the ſcale of ſpaces paſſed through by the ſhot in correſponding times, in its retarded movement of impulſion. From this deduce the ſcale of correſponding velocities M N O P Q, and that of the momentaneous reſiſtance of the air to the motion of the ſhot; thus the retarding force of the air will be known.

196. It has hitherto been ſuppoſed that the ſhot is projected in the direction of the axis, but this does not always happen. To remedy this inconvenience; fire the gun with a charge that will produce a given initial velocity, place the butt (Fig. 26.) at different diſtances S $o$, S $l$, S $m$, S $n$,

taken at pleaſure, and meaſure the velocity with which the ſhot impinges on the butt, either by meaſuring its penetrations (176), or by ſome machine proper for the purpoſe. On a line, ſet off the abſciſſas S *o*, S *l*, S *m*, S *n*, equal to the ſpaces that the ſhot has paſſed through by its movement of impulſion; and let the correſponding ordinates equal the experimented velocities: then by making the longeſt ordinate equal to the given initial velocity, and erecting it at the beginning of the abſciſſas, we ſhall have the ſcale of velocities in correſponding ſpaces with a retarded movement of impulſion; from this ſcale may be deduced that of the momentaneous reſiſtances of the air to the motion of the ſhot; it is a matter of no conſequence for theſe experiments, whether the ſhot be projected in the direction of the axis or not.

197. There are other methods of aſcertaining the path deſcribed by projectiles, and the retarding force of the air; but it is to be preſumed that the principles laid down in the courſe of this treatiſe will, from their practical utility and eaſy application, induce the ſtudents to exerciſe themſelves in the theory of gunnery, whence they may derive from the uſe of fire-arms, particularly of mortars, advantages which can by no other means be obtained.

*Fig. 3.* *Plate 1.st*

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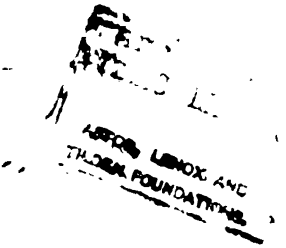
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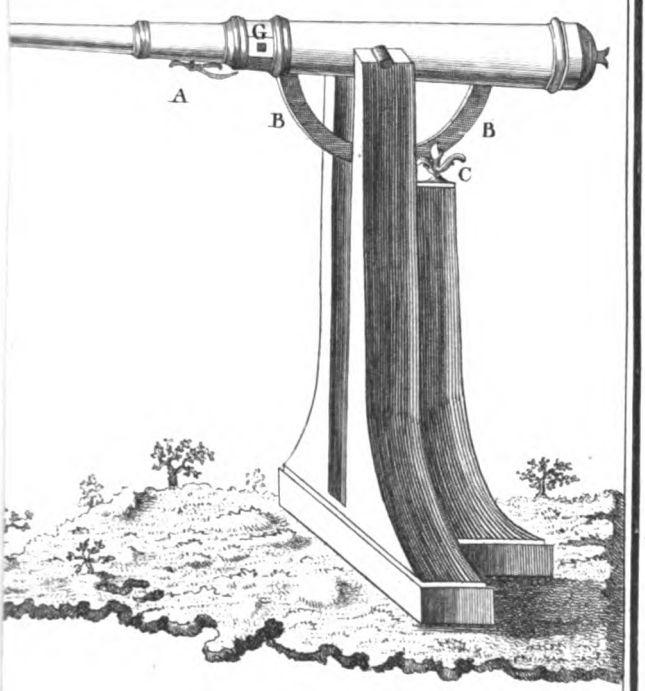
*Plate 2.d*

*Fig. 5,*

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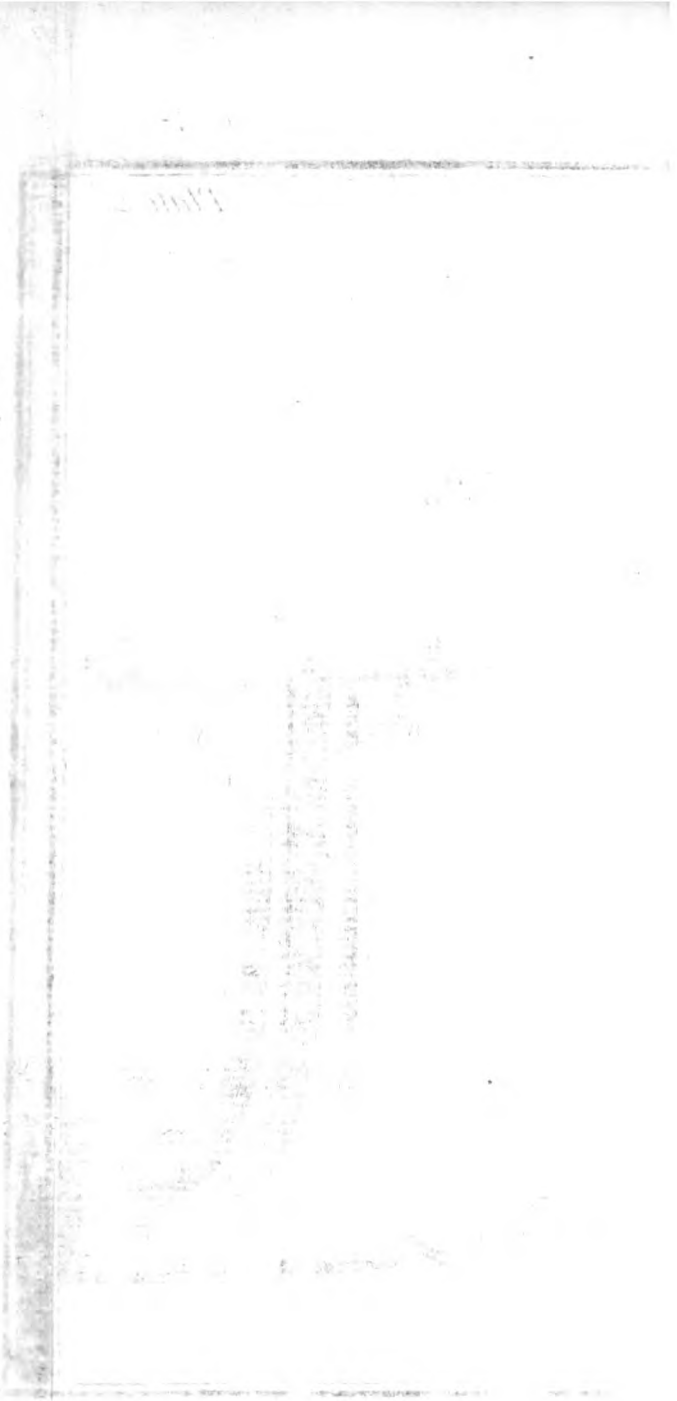

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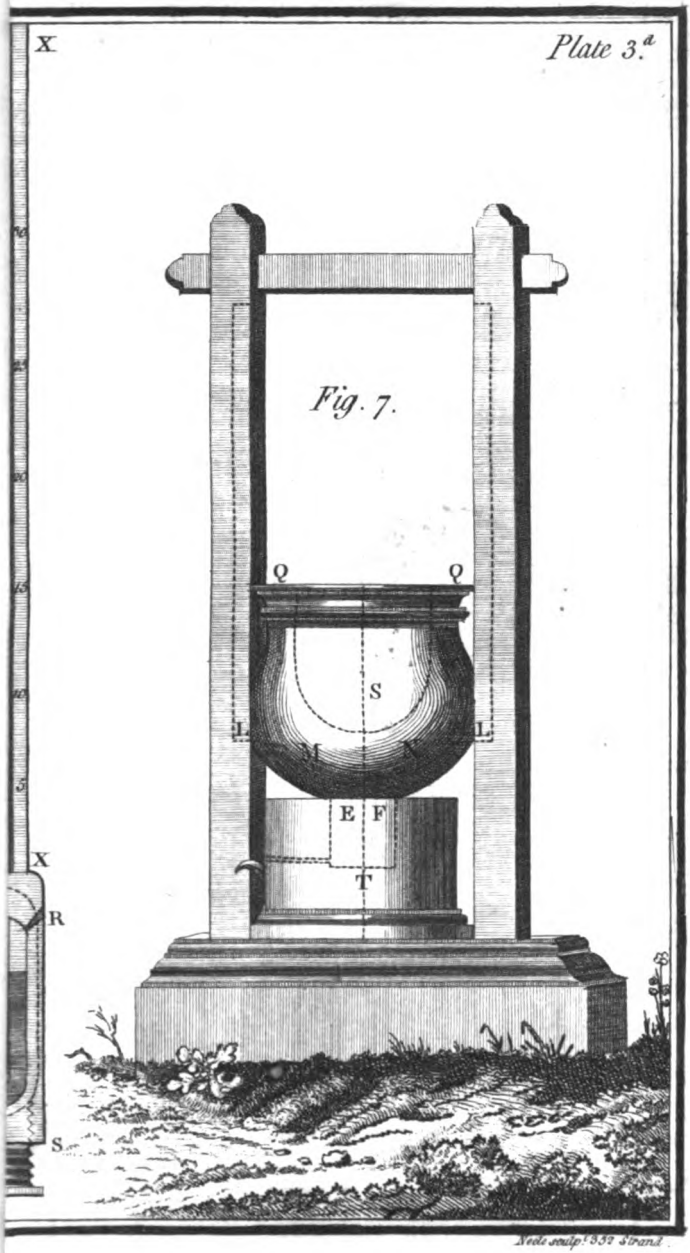
Plate 3.a
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Fig. 7.
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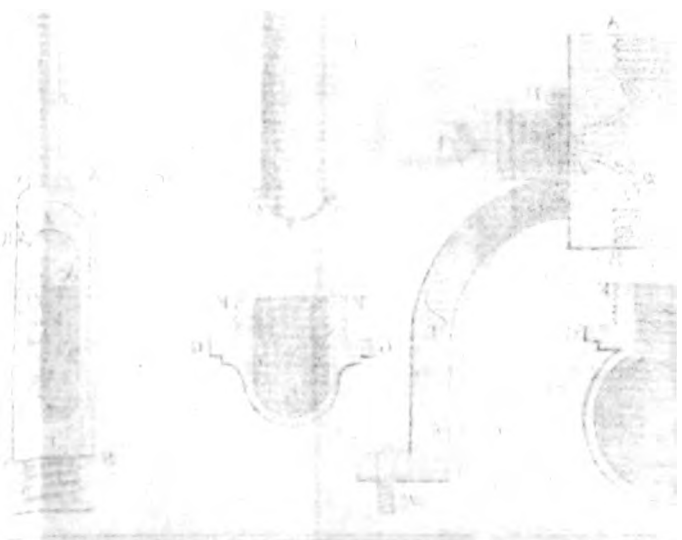

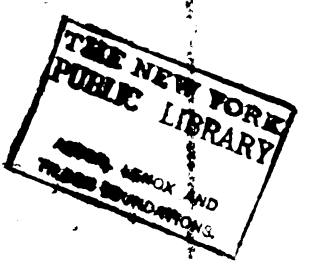
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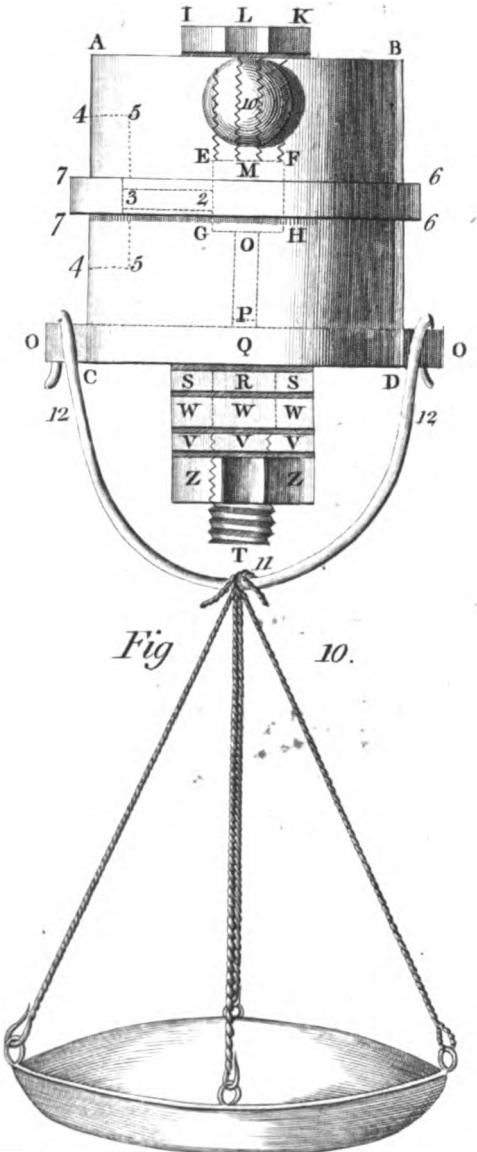


Fig 10.

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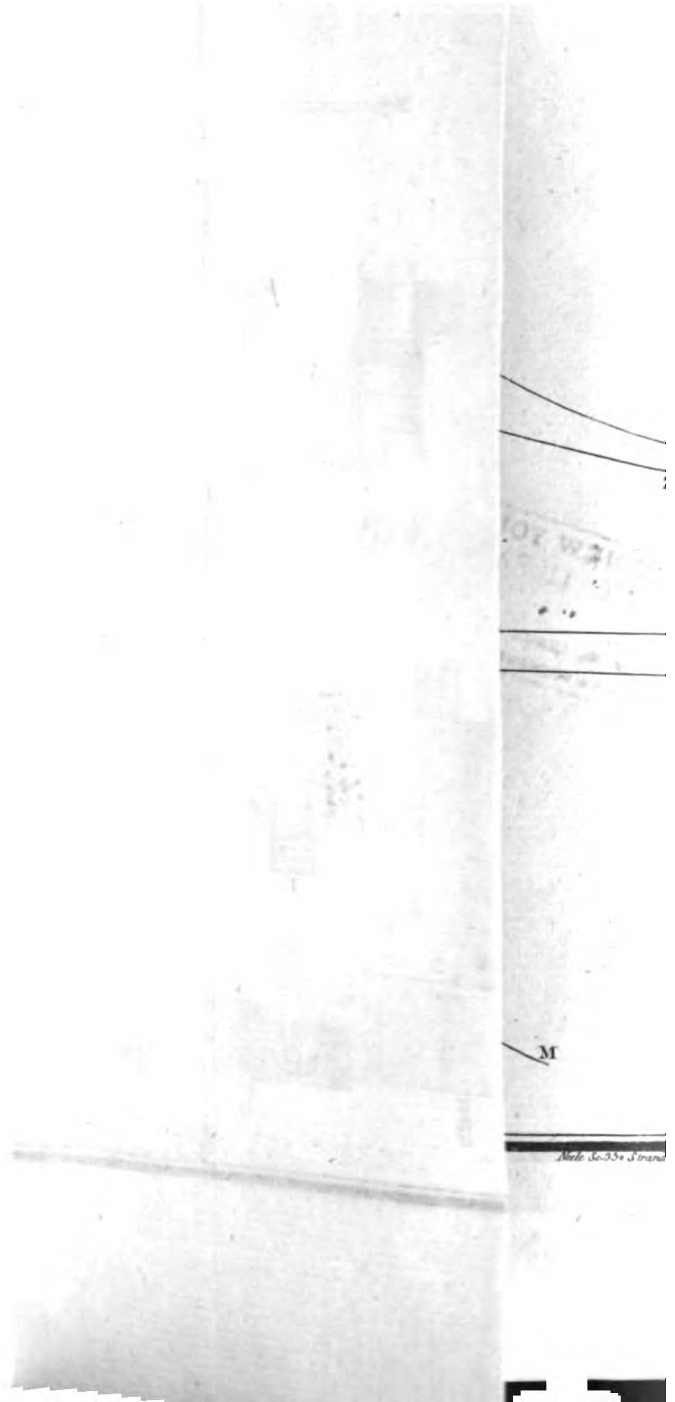
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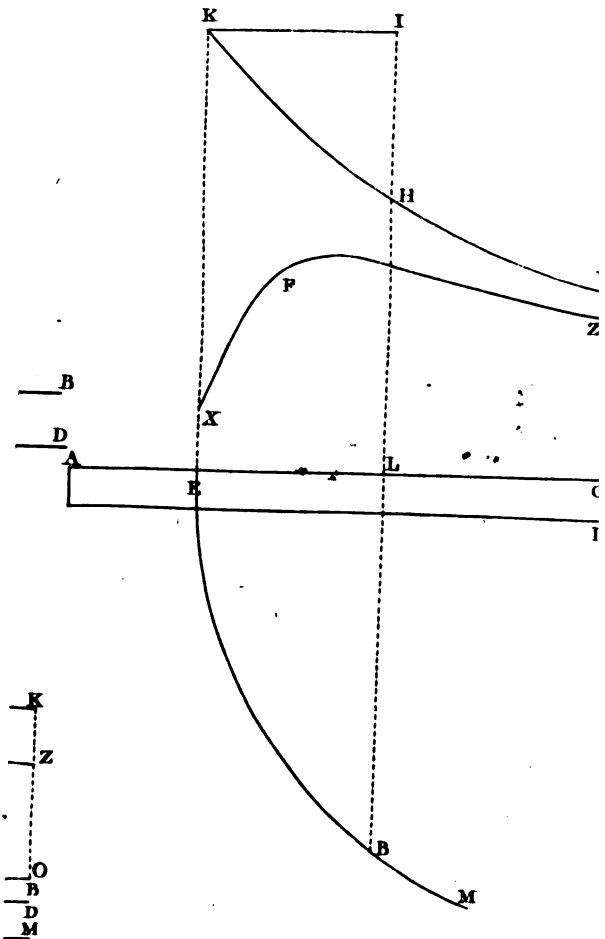
*Fig. 15.*



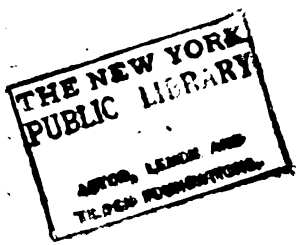

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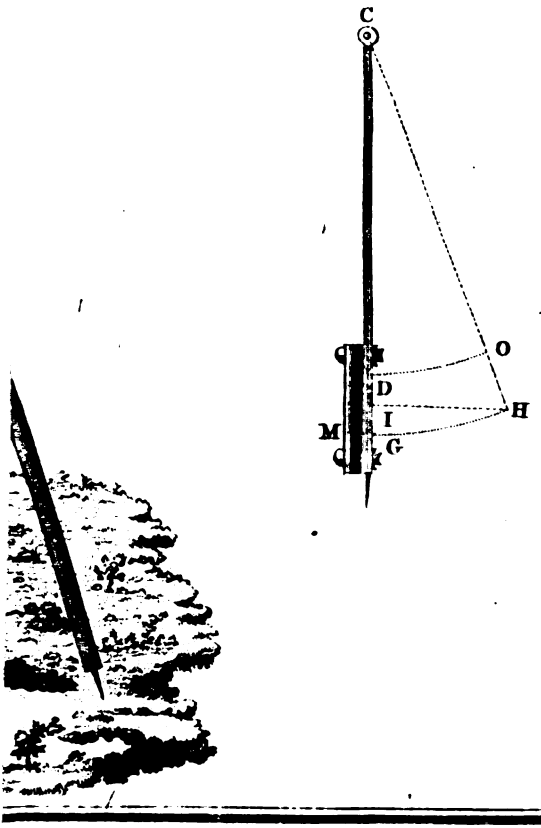
*Plate 6th.*

*Fig. 18.*

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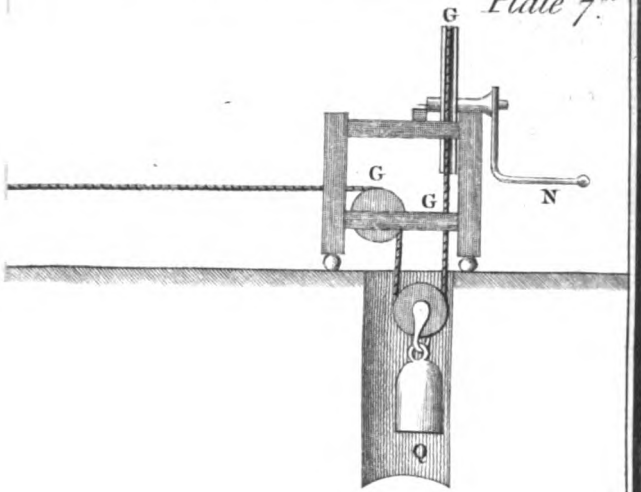


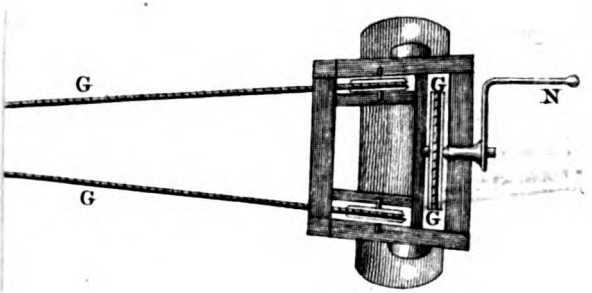


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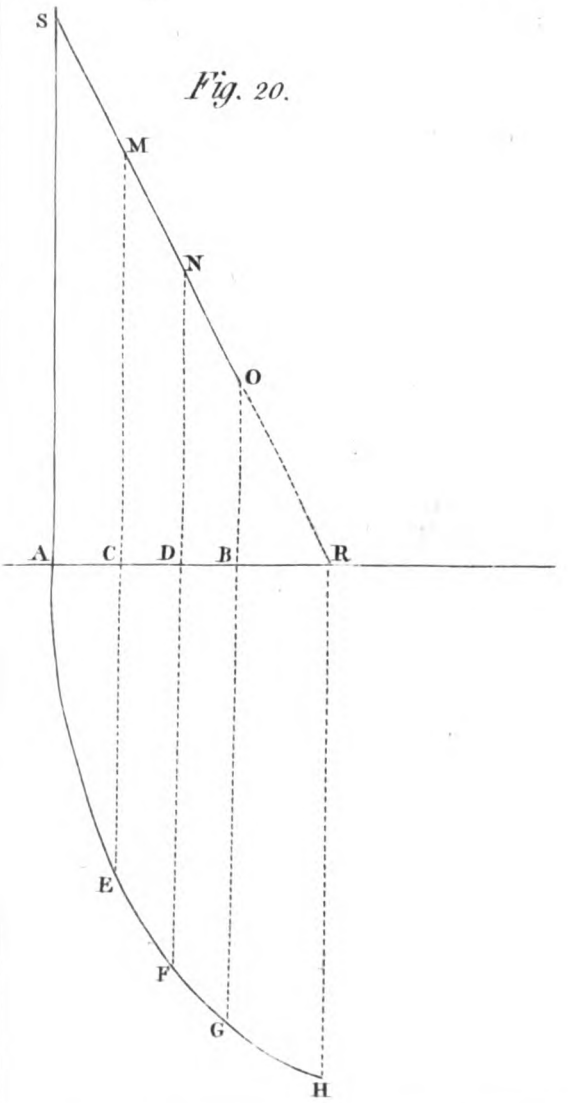
Fig. 20.

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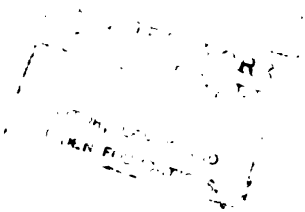

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# TREATISE

ON

# FIRE-ARMS.

## FIRST PART.

### OF THE RESISTANCE OF FIRE-ARMS TO THE ACTION OF POWDER.

*The Metal of which any Fire-arm is made ought to have certain determined Phyſical Qualities, combined in ſo juſt a manner with the Thickneſs of the Piece, that it may be able to reſiſt the Exploſion of the Powder, without being unneceſſarily heavy and unweildy.*

THE earlier ARTILLERISTS, convinced from experience of the juſtneſs of this remark, ſubſtituted in the room of iron ordnance, guns and mortars caſt of BRONZE, a metal compoſed of tin and copper; to which they ſometimes added a proportion of braſs: hoping that this mixture would poſſeſs the ſeveral qualities in which the iron ordnance had proved defective.

2. Bronze was in uſe before the invention of gun-powder. It had long been known that a mixture of tin with copper was leſs tenacious and malleable, but harder than pure copper; and that it even became ſhort and brittle, if the tin were in too great a quantity. Wherefore the two metals were proportioned



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portioned according to the different uſes for which the bronze was deſigned: for caſting ſtatues, machines, &c. which required nice workmanſhip, the tin was generally between a 20th and 50th of the copper, and to give this ſoft metal a fine colour, they added a proportion of braſs, between a 3d and 5th of the whole. For bell-metal, which ſhould be very hard and entirely free from the ſeparations of the particles of metal found in bronze containing too little tin, no braſs was uſed, and the tin was in the ratio of 22 to 27 in the 100 of copper.

3. PETER SARDI, an *Italian*, who fully knew the properties of ſimple and compound metals, publiſhed in the beginning of laſt century, ſome obſervations on the damage that cannon ſuſtain from the exploſion of powder: wherein he pointed out the neceſſity of having a *metal that ſhould be uniformly hard, firm and reſiſting, not brittle like glaſs, ſoft like copper, nor liable to corrode like braſs; but which ſhould be able to ſtand repeated firings without ſuſtaining the leaſt injury.* Theſe ideas from their juſtneſs and accuracy ſoon ſpread from ITALY, in that day the ſchool of military ſcience, throughout all EUROPE; and the *Pyrotechnicia* of *Vannuccio Biringuccio* had already paſſed through ſeveral editions: it was natural therefore to ſuppoſe that the quality of bronze moſt proper for artillery would have been univerſally adopted, and a certain proportion of the component metals fixed on. On the contrary, the moſt enlightened and warlike nations proceeded without any determined principles, and various compoſitions were in uſe till the middle of this century; as may be gathered from the numerous publications on the ſubject.

4. This variety of opinions gave riſe to two parties: the *Italians*, deſirous of having a gun-metal hard and free from cavities, mixed the tin and copper in the ratio of 12 to 20 in the 100; and by applying a *bouch*, repaired the guns when the vents had run. The *oppoſite party*, conſidering tenacity as the moſt eſſential quality, mixed the tin with the copper in the proportion of 4 to 8 in the 100; and maintained that this compoſition was the beſt, as the vents were not ſo ſoon affected by the fire; and attributed the alteration in the bores of the guns, whence they were ſoon rendered unſerviceable, to any other than the true cauſe, which was the ſoftneſs of the metal. So long as powder was made of a weak quality, and the guns were not over-heated by too quick a ſucceſſion of

of diſcharges; as formerly in the hotteſt ſieges the firing having been kept up for ſome time in the morning was diſcontinued on both ſides for three or four hours; this queſtion remained undecided: but ſince the powder has been made ſtronger, and the firing has continued inceſſantly from morning till night, ſo many accidents have happened owing to the ſoftneſs of the metal, that there has been an abſolute neceſſity for increaſing the quantity of tin.

5. On ſurveying, after the peace of 1713, the artillery in the ſeveral fortreſſes in PIEDMONT; it was found that the viciſſitudes of the preceding war had introduced guns of all natures, caſt by founders of different nations. In the wars of 1733 and 1742, ſome of theſe pieces continued perfectly good after 1000 rounds; while others became unſerviceable after 500, or even fewer diſcharges: as the ſhot in ſtriking againſt the ſides had conſiderably altered the figure of the bore. Many experiments have been made in this capital ſince the peace of 1749, both by the officers of the royal corps of artillery, and by individuals appointed for the inveſtigation of particular points, to aſcertain the cauſe of this great diverſity of effects. This treatiſe being only an application of the principles of natural philoſophy to artillery, it will be beſt to purſue the method adopted in the preceding works, and refer to the maxims already eſtabliſhed; that the artilleriſt may take in at one point of view their riſe, connection and deduction, and be thereby enabled with the greater readineſs to apply them to practice.

6. Before we attempt to aſcertain the beſt conſtruction for fire-arms, it will be proper to conſider in what their perfection conſiſts; that from a clear diſcrimination of the neceſſity and importance of each particular point, we may avoid the error into which many have fallen, of paying attention to ſome circumſtances while they neglected others equally eſſential; thus loſing the advantages reſulting from a combination of the ſeveral parts of the ſubject: hence their labours have only tended uſeleſſly to multiply the ſpecies of ordnance, which has been already obſerved by ſome excellent writers; who from the badneſs of the inventions have inferred the want of talents in the inventors.

7. There are two principal conditions which conſtitute the perfection of every fire-arm: the firſt requires *that it be ſo conſtructed that the men who work it may run no riſk of being*

*hurt by it:* the ſecond, *that it be manageable and adequate to every purpoſe for which it is intended.*

8. To be poſſeſſed of the firſt condition (7); the quality of the metal, of which any gun is made, ſhould be in ſuch a juſt combination with its thickneſſes; that if by any extraordinary accident it burſt, it may not be ſhivered into pieces. This property is obtained by mixing the metals in a due proportion.

2. The bore of the gun ſhould be free from cavities, particularly in the charging cylinder; and of ſuch a figure, that with the ſponge the gunner may be able to extinguiſh any fire that hangs in the piece, in order to avoid the dreadful accidents that ſometimes happen in reloading.

3. Guns intended for works or batteries ſhould be of ſuch a length that the exploſion may not damage the embrazures, and that there be no neceſſity for making the inner part of them too wide; which greatly expoſes the artillery men to the fire of the enemy's muſquetry, to the evident detriment and delay of the ſervice.

9. The ſecond condition (7) requires;

1. That the metal be of ſo tenacious quality that the gun may with a moderate thickneſs for a long time reſiſt the force that tends to burſt it: as guns of large calibre may on this principle be made lighter, and be conſequently more eaſily worked and brought into action. The metal ſhould likewiſe be of ſo hard a nature, that the bore of the piece may ſuſtain without alteration a long continued firing.

2. That in diminiſhing the weight of metal, ſuch regard be paid to the figure of the gun, and the poſition of the trunnions, that no irregularity of movement can take place at the diſcharge, ſufficient to damage the bore of the gun, or alter the direction of the ſhot.

3. That all the parts and ornaments be ſo proportioned and ſituated as to be of ſervice in laying the gun and firing with preciſion.

After theſe preliminary obſervations, let us proceed to examine ſeparately the ſeveral cauſes that conduce to the perfection of fire-arms.

CHAP.

## CHAP. I.

### OF THE METALS OF WHICH FIRE-ARMS ARE MADE.

10. THE ſimple metals uſed in caſting cannon, are *iron, copper and tin*; *braſs*, which is a compoſition, is ſometimes added. As the proprietors of mines find it too expenſive to perform all the operations neceſſary for the thorough purification of the metals, the iron and copper uſually met with in commerce, are not ſufficiently refined for the purpoſe of the founder. The ſubſequent remarks on the method of uſing theſe metals will alſo point out when they are properly purified.

11. *Iron ore* is generally found in the form of an indurated earth, and is fluxed in contact with charcoal, with a very ſtrong heat kept up by means of large bellows: during this operation the greater part of the volatile particles contained in the ore, as ſulphur and arſenic, exhale in form of ſmoke, and the phlogiſton uniting itſelf intimately with the ferruginous particles, the iron appears in fuſion at the bottom of the furnace; whence it is run into a trough prepared with ſand of a demi-cylindrical form, and is by the workmen termed *a pig*. This is called iron of the firſt ſmelting, and is always unmalleable.

12. This iron is again ſmelted by a ſimilar proceſs, and is then called iron of the ſecond ſmelting, which though purer than the firſt, is ſtill unmalleable. In proportion as the ore is more purified and has been oftner ſmelted, it fuſes with more difficulty; and the fuſion does not at length commence till the heat be very intenſe.

13. The iron procured from foreign countries, as an article of commerce is generally diſtinguiſhed into two ſorts. The one does not yield to the hammer when cold; but when red hot, it eaſily breaks into pieces, which is owing to the quantity of heterogeneous ſubſtances it contains, principally arſenic and ſulphur; the other kind is malleable when red-hot; a certain ſign that it is well purified and of a good and tenacious quality.

14. For iron guns, the ore of the moſt tenacious quality is the beſt. Engliſh ore is in the higheſt eſtimation; it has

a ſufficient degree of hardneſs, ſince in firing with ſhot, the bore of the gun is never injured; but as it is not ſufficiently tenacious to reſiſt the force of powder in very long ſieges, it becomes neceſſary to ſupply this defect by adding to the ſtrength, and conſequently to the weight of the guns, to prevent their burſting: wherefore 32 pounders with proper reinforces are too heavy, and are only uſed on board of ſhips of war, 24 pounders being the largeſt piece of iron ordnance that is uſed in land ſervice.

15. The iron of the ſecond fmelting is heated and welded with a forge hammer to increaſe its malleability and tenacity: this operation is frequently repeated to ſeparate the earthy heterogenous particles. When thus worked, it obtains the name of forged iron, and is leſs hard but much more tenacious than before. It is eſteemed of the beſt quality when malleable, both hot and cold, and when it yields to the file; but when it breaks and ſplits under the hammer, it is not ſo good. A very violent and long continued heat is neceſſary to fuſe forged iron; and from its ſoftneſs, it is only uſed in the conſtruction of fire-arms of ſmall calibre, from which leaden bullets are projected, as wall-pieces, muſquets, piſtols, &c. ſince from its great tenacity the barrels may be made very thin.

16. *Copper* is generally found mixed with other metallic and volatile ſubſtances; according to the nature and proportion of which the operation of purifying muſt be varied. It ſometimes happens that a vein of a copper mine will furniſh for a conſiderable time, an ore eaſily refined; but at length its quality alters, which induces a neceſſity of multiplying and even diverſifying the proceſſes of refining. In all caſes it is firſt fluxed; whence a *regulus* or mixed metal, called *black copper* is obtained; which is unmalleable and of different qualities according to the nature and proportion of the heterogeneous ſubſtances.

17. To purify black copper, the chymiſts uſe the *capel* almoſt the ſame manner as the refiners of gold and ſilver: but the common method is to roaſt and afterwards fmelt it; that during the roaſting, the volatile particles may be ſublimed; and that when in fuſion the other heterogeneous ſubſtances may be converted into ſcoriæ: the metal obtained from this proceſs is called copper, and is generally run into thin cakes, which are very full of cavities and ſpungy.

The

The copper met with in commerce is generally deſigned of three qualities, viz. *pure*, *common*, and *impure*, as in ſome mines the metal will not defray the expence of purifying it. For ſome years paſt the merchants have imported copper from GERMANY, SAVOY, and JAPAN, which is very well purified: that procured from AOST and SWEDEN is harder and leſs malleable; but the copper brought from MEXICO is of a very inferior quality, being crude and totally unfit for wire-drawing.

18. Pure copper is red, tenacious, ductile and malleable; it is drawn into very ſmall wire, as the ſtrings of muſical inſtruments; and beat into very thin veſſels without breaking or ſplitting: this is a certain method of proving its purity. This copper requires a very ſtrong and long continued heat to melt it. If it be fuſed without being in contact with any phlogiſtic body, and the fire be ſtronger than is neceſſary to keep it in fuſion, ſmall particles will be ſeen ſucceſſively to calcine; and if the ſame force of fire be continued, theſe calcinations will appear in the form of ſcoriæ floating on the ſurface of the melted metal. If the ſcoriæ be ſcummed off, pounded and mixed with a quantity of charcoal, they will when expoſed in the furnace to a ſtrong blaſt revivify and reſume the metallic form. (Philoſ. Inſtit. 91, 116.)

The flame that breaks out at the fuſion of pure copper with charcoal, is of a fine green colour; when diſſolved by oil of vitriol, it exhibits a blue flame.

19. Common copper is that in which the heterogeneous ſubſtances are in ſmall quantity, and do not much affect its tenacity and ductility; ſo that though it cannot be drawn into very fine wire, kitchen utenſils are made of it.

The copper of the third kind is of an inferior quality; leſs tenacious and ductile: if brittle under the hammer, or when offered to the wire-drawer, it is a proof that it contains many ferruginous or arſenical particles. If there be much arſenic, the copper fuſes eaſily; and if there be any antimony it accelerates the fuſion: but then the flame inſtead of being of a greeniſh is of a whitiſh caſt, and is loaded with ſmoke. If the flame at the ſolution of copper by oil of vitriol be yellow, it is a ſign that the ore contains iron; and if the colour become green, the iron is in great quantity. Impure copper ought never to be admitted into founderies for cannon, as the bronze made of it is ſhort and brittle.

20. *Tin*

20. *Tin* is the lighteſt of metals; yet its ore is very ponderous when mixed with arſenic: it is therefore eaſily ſeparable from other heterogeneous ſubſtances that are lighter, either by picking or waſhing, after it has been pounded in a mortar: the ore is then roaſted to clear it of the arſenic, and afterwards ſmelted in contact with ſubſtances abounding with phlogiſton; in order to prevent the great calcination to which tin in fuſion is liable.

21. Tin well purified is not very ductile or tenacious; and a creaking noiſe on bending it different ways is heard. A very moderate degree of heat fuſes it long before it becomes red, and the more it is expoſed to the air the ſooner it calcines: on combining the calx with a phlogiſton, and expoſing it to a proper degree of fire, it readily reſumes the metallic form. Purified tin is miſcible with other melted metals, and diminiſhes their ductility and tenacity, excepting lead. On the other hand, a mixture of 20 parts of tin and 1 of copper, is more ſolid than pure tin, and yet preſerves its ductility; of this kind is the fine Engliſh tin.

22. *Zinc* is a ſemi-metal found in *Calamine*, *Lapis Calaminaris*, and the ſubſtance called *Cadmia Fornacum* which attaches itſelf to the mouth of furnaces, in which metals containing zinc have been ſmelted. This ſemi-metal eaſily inflames, when expoſed to a ſufficient degree of heat, ſublimes in the form of white flowers, called *philoſophic wool*, and is diſſipated. As zinc is found mixed with different minerals, the operation of purifying it varies according to their ſeveral qualities.

23. The combination of *zinc* with *copper* is called braſs. When the ſubſtances are of a good quality, the braſs is malleable when cold; brittle, when very hot: but if compoſed of impure materials, it is brittle when cold: from this property its quality is eaſily aſcertained. Braſs is yellow and more fuſible than copper: if fuſed in a crucible with a ſtrong heat, the melted metal will inflame and a great many flowers of zinc be ſeen to riſe from its ſurface; ſo that if it be kept a long time in fuſion, it will loſe all its *zinc*, and the reſiduum will be ſimply copper.

24. If a quantity of copper be heated, and a proportion of tin thrown into the furnace, the two metals will ſooner become fluid: if copper, or a mixture of it with tin be already melted, an addition of tin will render the fuſion thinner; tin is then the menſtruum of copper: but this property does not

not ſuffice to make a thorough and exact mixture of the two metals in large furnaces; a motion infinitely greater than that which is ſufficient to keep them in fuſion muſt be for this purpoſe excited. If the metals be well mixed together and drawn from the furnace ſo as to be ſuddenly condenſed; the particles will retain their intimate connection when perfectly ſolid: but if the quantity of melted matter be very great, and the receiver of ſuch a form that it is ſome time before it ſets, on examining it when cold, the tin will be found to abound moſt towards the bottom, particularly in long receivers, like the moulds of cannon. The calcinations (18, 21) which take place while the compoſition is in fuſion, are of different characters according to the quantity of melted metal, the expoſure of its ſurface to the air, and the time that it remains in fuſion: theſe changes are almoſt imperceptible in the more minute proceſſes of the metallurgiſts; but when in large furnaces a great quantity of metal is ſuffered to remain a long time in fuſion, and the fire is increaſed, it will be found that the metal produced from the revivified calcinations, contains the tin in a greater proportion, than when put into the furnace; as is ſeen in the refined cakes, which the founders of artillery draw from what they call *the operation of the handle*.

25. The mixture of *copper* with *tin* is called *bronze*, whatever be the proportion between the component parts, provided that the exceſs be on the ſide of the copper. In proportion to the quantity of tin, the compoſition (2) is harder and leſs ſubject to cavities; it even loſes its tenacity and becomes crude and brittle, if the quantity of tin be too great; the addition of a conſiderable proportion of braſs renders it a little harder, and even more brittle when heated (23) though the braſs be of the beſt quality. Since the uſe for which the bronze is deſigned muſt determine the proportion between the component parts, in order that it may have the phyſical properties requiſite for the intended work (2, 3), it follows that guns may be caſt from bell-metal, and ſtatues, &c. from gun-metal, on adding certain quantities of copper or tin.

26. It will be ſhewn in the following chapter that the metal for caſting cannon, particularly battering cannon, muſt (8, 9) indiſpenſably be of a hard and tenacious nature. To this end it is neceſſary;

1 That the metals be of a good quality and well purified.

2. That

2. That their proportion be compriſed within certain limits.

3. That their natural hardneſs and tenacity be increaſed by compreſſion.

27. Pure copper (18) is the beſt for artillery; as is the Engliſh tin (21) on account of its ſuperior quality. Tin in which there is any *lead* ſhould be abſolutely rejected, ſince this metal diminiſhes both the tenacity and hardneſs. That gun-metal may have all the requiſite properties (26), the quantity of tin ſhould be between a 6th and an 8th part of the copper, when the powder is as ſtrong as that now in uſe: it would be injudicious to diminiſh the proportion, as was done when the powder was weaker. If the copper be very well purified, and conſequently very ſoft and ductile, the quantity of tin ſhould be nearly 16 in the 100 of copper; but not more than 12 in the 100, if the copper be of an ordinary quality; 12lb. of tin mixed with 100lb. of impure copper form a crude and brittle bronze, and ſhould never be uſed. In order to increaſe by compreſſion the natural hardneſs and tenacity of the metals, the moulds of guns ſhould be ſo made, that the ſuperincumbent maſs, commonly called the *head*, be as long as poſſible.

28. Whenever braſs enters into the compoſition of gun-metal, it ſhould be in ſmall quantities; ſince, as has been already obſerved, it tends to render it brittle, particularly when the gun is heated by frequent firing (23, 25): beſides, as it muſt be put into large furnaces by ſmall quantities at a time, the zinc of the braſs firſt introduced will be ſublimed (23); which cauſes an uncertainty with regard to the juſt proportion of the materials. The advocates for the uſe of braſs think that it aſſiſts and preſerves the perfect mixture between the copper and tin; but this opinion is not ſufficiently warranted by experience.

29. To the remarks already made on the hardneſs of ſome particular metals (Inſtit. Phyſ. Mec. 66), let us add the reſult of *experiments made on ſeveral compoſitions* in 1759 by MAJOR RONZINI, *director of the royal laboratory of metallurgy*. In theſe experiments, ſeveral rods of metal were expoſed to the force of a piece of iron weighing 8½lb. which falling from the height of 1½ foot, on the head of a ſteel punch with a conical point drove it into the rod of metal, upon which it reſted; the effects are therefore expreſſed by the ſize of the holes made by the punch, which from the ſimilarity

of

of the figures, are in the triplicate ratio of the penetrations, marked in the firſt column; and the relative hardneſs of the rods are expreſſed in the inverſe ratio of theſe holes; for example, the hardneſs of the bronze A is to the hardneſs of the bronze F as 173 to 51.

Reſult of experiments made in 1759 to compare the relative hardneſs of the following metals:

| | The relative Penetrations of the punch into the Rods. *Firſt Column.* | Effects expreſſed by the relative ſizes of the holes made by the punch. *Second Column.* |
|---|---|---|
| Fine tin of England | 92 | 1216 |
| Pure copper of Germany | 66 | 450 |
| Small pieces of copper coin | 58 | 301 |
| Braſs of Germany, malleable when cold | 54 | 246 |
| A mixture of 100 parts of copper, 12 of tin, and 2 of zinc, the zinc being previouſly mixed with the tin | 42 | 116 |
| A mixture of 100 parts of braſs and 12 of tin. | 35 | 68 |

Bronze formed of good Materials in the following Proportions.

| | | *Copper.* | *Tin.* | *Braſs.* | 1*ſt. Col.* | 2*d. Col.* |
|---|---|---|---|---|---|---|
| Different Mixtures. | A | 100 | 25 | " | 32 | 51 |
| | B | 100 | 20 | " | 35 | 66 |
| | C | 100 | 16 | " | 37 | 78 |
| | D | 100 | 14 | " | 40 | 100 |
| | E | 100 | 12 | " | 42 | 116 |
| | F | 100 | 8 | " | 48 | 173 |
| | G | 100 | 24 | 100 | 37 | 78 |
| | H | 100 | 20 | 5 | 34 | 62 |
| | K | 100 | 16 | 28 | 36 | 73 |
| | L | 100 | 14 | 8 | 37 | 78 |
| | M | 100 | 12 | 6 | 40 | 100 |
| | N | 100 | 10 | 12 | 42 | 116 |
| | P | 100 | 9 | 20 | 44 | 133 |
| | Q | 100 | 8 | 28 | 47 | 162 |
| | R | 100 | 5 | 20 | 49 | 184 |
| | T | 100 | 2 | 20 | 52 | 220 |

30. We gather from these experiments;

1. That tin is the principal ingredient towards rendering the bronze hard.

2. That the holes made in the metals A, B, C, D, E, F, composed only of copper and tin are nearly in the reciprocal ratio of the quantities of tin.

3. That by adding a quantity of brass, the proportion of the ingredients may be diversified, yet retain the same hardness, as appears from G and L.

4. That the metals C, D, whose component parts are within the limits assigned (27) may serve as a rule to judge whether the other metals have the requisite hardness for artillery. For example, to compare the hardness of a bronze Z with that of C or D; let the penetration of a punch falling on a piece of fine English tin of a determined quality = I, then find the penetration of the same punch into the bronze proposed, and express it by Z; $\frac{I}{Z}$ will be the proportion between these penetrations. But by the experiments in the preceding paragraph $\frac{92}{40}$ is the proportion between the penetrations into the tin and the bronze D. If then $\frac{I}{Z} = \frac{92}{40}$, the proposed bronze Z will be as hard as the given bronze D; If $\frac{I}{Z} > \frac{92}{40}$ Z will be harder than D, and if $\frac{I}{Z} < \frac{92}{40}$, D will be harder than Z.

31. There are different methods of finding the proportion of tin in any bronze, but they give at best but an approximation.

In the first place, the composition of a bronze may be determined by finding experimentally its hardness and tenacity, and comparing them with the hardness (29) and tenacity (Instit. Phys. Mic. 64.) of a bronze given as a rule; if they correspond in these two properties, they may be said to be of the same quality; but if one be equally tenacious, but less hard than the other, or equally

equally hard and leſs tenacious; it will be a proof that the proportion or quality of the component metals is different.

In the ſecond place, the compoſition of bronze may be nearly aſcertained by ſound and colour; for if on ſtriking it with a hammer, it be very ſonorous, the tin abounds, and vice verſâ. When the filings of bronze appear red, it contains but little tin; when they appear ſparkling and whitiſh, the tin is in great quantity: a yellow colour denotes that there is a great proportion of braſs. If a piece of bronze be broken off with a hammer, and at the point of ſeparation hardly any particles of copper can be perceived, it is a ſign that the proportion of tin is about $\frac{1}{6}$ of the copper; greater than $\frac{1}{6}$ when the ſection appears of a whitiſh caſt; and leſs when many particles of copper are perceptible.

In the third place, ſome idea may be formed of the proportion between the tin and copper, by knowing the quality of each, and aſcertaining their ſpecific gravities; but this method is not accurate, on account of the ſpungineſs of the copper.

## CHAP. II.

### Of the Hardness and Tenacity of Gun-metal.

32. TO prove more clearly the neceſſity of having a hard and tenacious metal for caſting guns, and be enabled to aſſign certain limits to theſe two properties, ſo that the pieces may be ſufficiently ſtrong, without unneceſſarily increaſing their weight or incurring other inconveniences (8, 9), the forces that tend to deſtroy the guns, and the manner in which theſe forces act, ſhould be conſidered.

Fired powder tends to deſtroy guns in three different ways.

1. By the preſſure of the elaſtic fluid againſt the inſide of the cylinder.

2. By the effects produced by a wad, or other ſimilar ſubſtance, when placed at a conſiderable diſtance from the powder, if the charge be ſmall, or contiguous to it, if the charge be ſuperabundantly large: for in either

either caſe, the elaſtic fluid generated at the bottom of the cylinder, is ſo much accelerated in its motion before it reaches the reſiſting body, that it acts with great force, and meeting with obſtruction exerts againſt the ſides of the gun, a power much greater than that proceeding from the preſſure alone.

3. By the irregular motion of a ſhot, which ſtriking againſt the ſides, makes cavities and furrows, and alters the figure of the cylinder; which would render the gun liable to burſt, if the metal were not much thicker than neceſſary to reſiſt the preſſure of the elaſtic fluid.

33. To know how far tenacity combined with the thickneſs of metal can reſiſt the force of powder (32 No. 1, pl. 1, Fig. 1.) Let the figure repreſent a ſection of the charging cylinder at right angles to the axis of the piece, and $AB=r$ the radius of the bore BFGD, and $BC=m$ the thickneſs of metal: ſuppoſe $m=$ the diameter BD, the theorem $9962\,nr=mq$ is the expreſſion of a cylinder, which burſts longitudinally, and $m=2r$; then ſubſtituting this value, and correcting the expreſſion $4981\,n=q$; $n$ ſhews how often the fluid generated from powder is more elaſtic than the natural air under a mean ſtate of the atmoſphere, and $q$ expreſſes in pounds the weight requiſite to overcome the tenacity of the metal. Suppoſe the elaſticity of the fluid be at the higheſt degree, *viz.* equal to that produced under a very dry ſtate of the atmoſphere, in a veſſel that invariably preſerves its form, whence it can only eſcape by the vent, $n=1900$ (Treatiſe on Powder 137): then $4981\times1900=9463900$ lbs. which is the tenacity repreſented by $q$ in a thickneſs of metal equal to the diameter of the bore and in equilibrio with the given preſſures. The tenacity of bronze compoſed of common copper and $\frac{1}{8}$ of tin is 12909386; and of bronze containg $\frac{1}{6}$ of tin 11881360 (Philoſ. Inſtit. 64); hence if either be uſed for caſting cannon in the proportions of heavy artillery, the tenacity will be greater than is requiſite; particularly as in practice, the greater part of the fluid eſcapes through the mouth of the gun, where it encounters no other reſiſtance than the friction of the wads, and weight of the ſhot, ſo that the elaſticity never amounts under the moſt favourable circumſtances to $\frac{3}{4}$ of the greateſt elaſticity 1900. Wherefore gun-metal may be compoſed of copper and $\frac{1}{6}$ of tin, without any riſk of the gun's burſting.

34. THE

34. THE OFFICERS OF ARTILLERY, in order to aſcertain whether guns caſt of the mixture M (29) oppoſed ſufficient reſiſtance to the greateſt preſſure of the elaſtic fluid, made choice of a 32 pr. called the *Invincible*, in which the thickneſs of metal at the breech was equal to one diameter of the bore, and the thickneſs at the end of the firſt reinforce equal to $\frac{15}{16}$ of that diameter. In the month of MAY, 1771, this gun was loaded with 16 lb. 6oz. of fine war powder, the wads were of twiſted hay, rammed down by ſix ſtrokes, from two gunners; the reſt of the cylinder was filled with clay very cloſely preſſed, and a tompion of wood wedged into the muzzle: the gun thus loaded was placed in a ditch, prepared for the purpoſe, and ſtrong ſtakes driven on each ſide to prevent the leaſt motion; a heavy beam was fixed behind the breech, and another before the muzzle, to force all the fluid to eſcape by a hole made in the axis of a bouch ſcrewed into the vent. The charge being ſet fire to, all the ſubſtances were forced through the mouth of the piece, and the beam placed there blown into the air. The gun was carefully examined, but not the leaſt flaw diſcovered, though every inſtrument and method were uſed for that purpoſe: it was afterward filled with water, and ſuffered to remain in that ſtate for five hours, at ſuch an elevation as to cauſe a ſtrong compreſſion, yet not a ſingle drop oozed through.

35. It has been already obſerved that metals loſe their tenacity when heated, and compound metals more than ſimple ones; wherefore *the oftener the guns are fired the leſs tenacious the metal becomes.* This heat however is never ſo great as to fire the powder in loading the piece; beſide the artillery men either ceaſe firing or cool the gun with a wet ſponge, when they are apprehenſive of its being too hot: wherefore we will conſider this heat as the higheſt term in comparing different tenacities. Bronze containg $\frac{1}{6}$ of tin loſes at moſt a third of its tenacity, when heated ſo as to fire powder; or in other words, its tenacity is only equal to 7358758; and bronze containing $\frac{1}{8}$ of tin and heated to the ſame degree loſes only a fourth of its tenacity, which is thus reduced to 9682040: then, if in the theorem $4981\,n=q$, 1200 be ſubſtituted in the place of $n$; (ſince (33) in the common firing $n<\frac{2}{3}\times 1900$,) $4981\times 1200=5977200$ equal to the

preſſure of the fluid: wherefore the tenacity of theſe metals heated ſo as fire powder, is ſtill greater than is neceſſary, when the thickneſs of metal at the charging cylinder is equal to a diameter of the bore.

36. The following experiments made by the OFFICERS OF ARTILLERY, in the ſpring 1770, at the PRACTICE BATTERY will prove the above propoſitions. A 32 pr. called the *Sarcophagus* conſtructed on the ſame model and of metal of the ſame quality as the *Invincible*, was fired 800 times with ſhot, the windage of which was agreeable to the preſent eſtabliſhment: the charge of 8 lb. 12 oz. of fine war powder was uſed; two gunners gave five ſtrokes to the wad over the powder, and three to that over the ſhot; the gun on its carriage was placed upon a horizontal platform; 100 rounds a day were fired at the rate of 12 in an hour, which is more frequent than in the hotteſt firing at ſieges, as on an average ſeldom more than 9 rounds can be fired. After the experiment, the piece was carefully examined, but no flaw diſcovered; the part of the cylinder from the muzzle to the wad over the powder was perfectly ſmooth, and the gun having been each time pointed to the *butt*, the ſhot were all thrown in a direct line; the inſide indeed of the charging cylinder was become rough; but this could not affect the ſervice of the gun, and was attributed to the liquefaction or calcination of the particles of tin that lay on its ſurface. It has often happened that on heating the breech of a gun, to repair the vent which had been enlarged by firing, the exterior ſurface has become very rough, and when the tin has not been properly mixed with the copper, little cavities have been formed: the irregular enlargement of the vent further proves a want of due exactneſs in mixing the metals.

The *Sarcophagus* had a chamber at the bottom of the cylinder, the upper part of which was conſiderably corroded by the powder that eſcaped through the vent; this will be accounted for in the eighth chapter.

37. Having thus conſidered the reſiſtance of guns with reſpect to their tenacity combined with the thickneſſes of metal, let us examine why hardneſs is likewiſe neceſſary, and how far this property ſhould be carried. For this purpoſe, the action of the fluid on the ſides of the gun, particularly at the part where the wad is placed between the powder and ſhot, muſt be known (32, No. 2). The eaſieſt and moſt effectual method

method of aſcertaining this, is to make experiments with two guns of the ſame calibre, but caſt from different mixtures: Let one gun be caſt from a ſoft mixture, in which the tin does not exceed $\frac{1}{20}$ of the copper; (Pl. 1, Fig. 2,) let the charge be equal to $\frac{2}{3}$ of the weight of the ſhot, and be wadded as uſual; after the diſcharge it will be ſeen that from A, where the ſhot was lodged, towards B the bottom of the bore, the ſides are diſtended all around, and the orbicular cavity A C D in ſhape of a pear is formed, whoſe greateſt depth is at C where the wad was placed between the powder and ſhot; that it diminiſhes gradually towards B, and ceaſes entirely at D, at the diſtance of about two diameters from B. On charging this gun with a quantity of powder equal to the weight of the ſhot, the cavity will be increaſed, but its greateſt depth will ſtill correſpond with the ſituation of the wad between the powder and ſhot. If, inſtead of being conſtructed according to the proportions of heavy artillery, the thickneſſes of metal be only in equilibrio with the fluid; the gun will burſt at the point of the greateſt depth of the cavity; or at leaſt the metal, if ſoft and ductile, will bulge out.

Let another gun be caſt on the ſame model from a harder metal, in which the tin is equal to $\frac{1}{8}$ of the copper, and undergo the ſame proof: after repeated firings no cavity or other alteration will be found, provided that it was properly reinforced; but if the thickneſſes of metal be only proportionate to the preſſure of the fluid, the gun will burſt where the wad is placed between the powder and ſhot. Other experiments will be adduced in the courſe of this work, more fully to evince the neceſſity of combining hardneſs with the thickneſs of metal.

Sportſmen know by experience, that though the barrels of their fowling-pieces may reſiſt ſtrong charges when the wad is contiguous to the powder; yet when a high wad is placed half a foot from it, even if the powder be of a weak quality, that they will burſt at that part. People unacquainted with the theory of the elaſtic fluid generated from fired powder, pretend that the burſting of the barrel is owing to the rarefaction of the atmoſpheric air intercepted between the powder and wad; but whoever knows how to eſtimate the force of this air, and compare it with the force which the fluid exerts againſt the wad, will be convinced that the action of the latter is the true cauſe.

38. The neceſſity of caſting guns of hard metal, in order to avoid the cavity (37) formed in the bore, is further demonſtrated by the following experiments made in June 1759, by the OFFICERS OF ARTILLERY. Three 16 prs. were conſtructed with the common proportions of battering guns, but each was caſt from a different compoſition; the firſt was the common mixture, that has been in uſe among our founders for ſeveral years, and contained tin in the ratio of 8 to 10 in the 100 lbs. of copper: the ſecond was the mixture R; and the third T (29). Three rounds being fired from theſe guns, under an angle of 15° with 8 lb. 12 oz. of powder; a cavity was found in each of them; with this difference, that its depth was greater in proportion as the metal contained leſs tin; for on meaſuring the cavities, the one in the gun caſt from the common mixture was $\frac{1}{12}$ of an inch, that in the gun from the mixture R $\frac{4}{12}$, and that in the gun from T $\frac{5}{12}$. Two ſhort 4 prs. one of which had been caſt from the common mixture, and the other from the mixture R, were likewiſe fired with 1 lb. 10 oz. of powder; the cavity in the former was $\frac{1}{24}$ of an inch, and that in the latter $\frac{2}{24}$.

39. The reſults of theſe experiments induced the officers to examine twenty 32 prs. which had been proved in the common method, by firing three rounds from each. They made uſe of the inſtrument invented by SIG. MATTEI, mathematical inſtrument-maker to the king, for taking the exact figure of the bores of guns. Ten of theſe guns had been proportioned on a ſcale made from the diameter of the ſhot, and caſt from the mixture R: they were fired with ſhot at the elevation of 15° with 16½ lbs. *of war powder*; on examination they were all found to have a cavity in the figure of a pear, where the wad was placed between the powder and ſhot; the cavity was two diameters in length, and $\frac{1}{12}$ of an inch in its greateſt depth. The other ten guns had been caſt from the common mixture, which was harder than R (29, 38), and proportioned on a ſcale made from the diameter of the bore: each of them was fired three times with ſhot at the elevation of 22½°, the firſt time with 17½ lb. of *cannon powder*, the ſecond time with 22 lbs. and the third with 26 lb. an orbicular cavity was likewiſe found after the laſt diſcharge in all theſe guns of about three diameters in length and $\frac{1}{12}$ of an inch in its greateſt depth, at the part where the wad had been placed in the laſt charge. Hence

appears

appears the neceſſity of having gun-metal ſo hard as not to admit of any cavity being formed by the action of the elaſtic fluid, which is more violent in proportion, as the charge occupies a greater length of the bore: wherefore, though *cannon powder* is leſs inflammable than *war powder*, (Treatiſe on Powder) and conſequently generates leſs elaſtic fluid in equal times; yet, in the guns formed of the common mixture, and fired with $26\frac{1}{4}$ lb. of cannon powder, the leſs quantity of fluid having a longer ſpace to paſs through, acquired greater velocity; ſo that notwithſtanding the ſuperior hardneſs of the metal, the cavity was of the ſame depth as in the guns caſt from R and charged with $16\frac{1}{2}$ lb. of war powder.

40. To confirm the reſult of the foregoing experiments, a 32 pr. caſt from the common mixture was, in Auguſt 1759, fired twice with each of the following charges of ſaluting powder, which was the ſtrongeſt then at hand; five ſtrokes were given by two gunners to the wad over the powder, and three to that over the ſhot: the piece was laid at the elevation of $22\frac{1}{2}°$.

EXPERIMENTS IN 1759.

| Weight of Powder. | | Length of Range, |
|---|---|---|
| *lb.* | *oz.* | *Yards.* |
| 9 | 4 | 3968 |
| 13 | 2 | 4456 |
| 16 | 6 | 4659 |

After the two firſt rounds, the gun was examined, but no cavity diſcovered; after the two rounds with the 13 lb. 2 oz. an orbicular cavity was formed, whoſe greateſt depth was $\frac{1}{12}$ of an inch, at the poſition of the wad between the powder and ſhot; and after the two rounds with the 16 lb. 6 oz. the cavity was much enlarged, its greateſt depth was $\frac{2}{12}$ of an inch at the place where the wad was lodged at the laſt diſcharge.

41. Some rounds were fired in September 1759, from an 8, 16, and 32 pr. caſt of a metal ſimilar to D, M, (29); in order to determine the proper degree of hardneſs for preventing the formation of orbicular cavities, even with extraordinary charges. The charge was of ſaluting powder, equal to $\frac{1}{4}$ of the weight of the ſhot; the guns were laid at 15°, and the wads rammed as before: after the experiment,

not the leaſt alteration could be obſerved in any of the guns; this degree of hardneſs may then be looked upon as ſufficient, and this concluſion has been fully juſtified by ſubſequent experience.

42. The third method, by which the powder tends to deſtroy guns (32, No. 3) now remains to be conſidered. In the wars of 1733 and 1742, there was an opportunity of examining guns of different nations, that had been rendered unſerviceable by the ſhot ſtriking againſt their ſides, and making cavities, furrows, cracks, and ſwellings, which had cauſed ſome of the ſhot to break to pieces in the guns, and cut the metal very deep; as appears from the reports made by the officers of artillery, appointed to examine them before they were recaſt.

Theſe accidents may be accounted for by the general cuſtom the nations of Europe had before the middle of the preſent century, of leaving it entirely to the founders to mix the metals; they, not aware of the neceſſity of having a certain tenacity and hardneſs, proceeded without any regular ſyſtem: whence frequently aroſe a remarkable difference in the reſiſtance of guns caſt by the ſame founder. In proving new guns, the charges occupied a great length of the bore; at the firſt round, the powder was equal to $\frac{2}{3}$ of the weight of the ſhot; at the ſecond to $\frac{5}{6}$; and at the third, was equal to it in weight: ſo that if the metal were not of ſufficient hardneſs, an orbicular cavity was formed at the poſition of the wad between the powder and ſhot, without the leaſt attention being paid to it: leſs charges being afterwards uſed on ſervice, the ſhot was placed in this very cavity, which cauſed it to take an oblique direction, and ſtrike againſt the ſides under angles of incidence, ſo much the greater as the cavity was the deeper; thus by degrees the gun was rendered unſerviceable.

43. The reſult of experiments made in May 1753, and in July 1759, will further ſhew the inconveniences ariſing from the formation of orbicular cavities in guns. For the firſt experiments, three 16 prs. were caſt of the common mixture (38) at the ſame time, and from the ſame furnace, to render the metal homogeneous, and for greater accuracy conſtructed with the ſame proportions; the only difference being in the calibre: for the diameter of the ſhot being divided into 8290 parts, the calibre of the ſmalleſt gun was 8463 of thoſe parts, that of the ſecond 8505, and that

of

of the largeſt 8580. Shot perfectly ſpherical and well poliſhed were caſt for the occaſion; none were uſed that were not exactly 8290 of the ſame parts in diameter; the proportion between the calibre of the gun and the diameter of the ſhot was in the gun of the ſmalleſt calibre as 31 to 30, in that of the mean as 27 to 26, and in that of the largeſt as 22 to 21. They were firſt proved as uſual with three rounds, charged each time with 9 lb. 14 oz. of powder and laid at 15°, to ſee how the caſting had ſucceeded; no flaw appeared on examination, except at the poſition of the wad between the powder and ſhot, where there was a ſmall cavity; but its depth was not meaſured, as the inſtrument for that purpoſe had not then been invented (39).

In May 1753, theſe guns mounted on their carriages, were placed on horizontal platforms, charged with 6½ lb. of powder, and directed towards the butt; fifty rounds were fired in the morning in the ſpace of four hours, and an equal number in the afternoon, in the ſame time. The principal object being to obſerve in what manner the guns were rendered unſerviceable, they were examined at firſt after every ten rounds; but ſo ſoon as the leaſt flaw was perceptible between the muzzle and the part where the ſhot was lodged, they were examined after every round. The gun of the medium calibre became firſt unſerviceable; ſome little cavities were formed between the 40th and 50th rounds: theſe increaſing in number and ſize, we obſerved between the 110th and 120th rounds ſeveral fiſſures; the muzzle alſo began to loſe its ſhape, the number and depth of the cavities increaſed from the 126th to the 137th; and at the 139th round the ſhot broke to pieces; the firing was then diſcontinued, as the muzzle would probably have *dropped* at the next round.

The next gun damaged was that of the ſmalleſt calibre; ſome ſmall cavities were perceived in the bore of this piece, between the 50th and 60th rounds, and ſeveral furrows between the 110th and 170th; at the 208th and 214th the furrows were much deeper, and the metal was cracked in ſeveral parts entirely through; theſe fiſſures increaſing between the 220th and 230th rounds, the gun became unſerviceable at the 233rd, when the ſhot came out in pieces.

In the gun of the largeſt calibre, ſome cavities appeared between the 30th and 40th rounds, and ſome furrows at the 130th, which enlarged at the 219th and 230th, with ſeveral fiſſures that penetrated to the exterior ſurface at the 240th round; and as they were ſtill increaſing, it was judged unneceſſary

neceſſary to fire this gun any more, though it was not entirely unſerviceable.

44. Other experiments were made in July 1759, with the three 16 pounders, already deſcribed (38) charged with 8¼ lb. of powder. After the formation of the orbicular cavity, ſome rounds were fired with 6½ lb. of powder, the ſhot with this charge lodging in the cavity; the gun caſt from T being leſs hard than the other two, and the cavity deeper, it became unſerviceable at the 14th round from the furrows and bulging in the ſides: the gun caſt from R being a little harder, and the cavity not ſo deep, became unſerviceable at 31 rounds; the third gun being of the hardeſt metal, was not unſerviceable after 146 rounds, though it bore evident marks of the impreſſion of the ſhot.

45. The experiments with the *Sarcophagus* (36) prove that when no cavity is formed in the bore, the ſhot do not ſtrike againſt the ſides, but quit the gun in the direction of its axis. The ſame has been obſerved of all the guns that from 1760 to the preſent time have been caſt from the new mixture, and uſed at the *Practice Battery* for the inſtruction of the artillery-men.

46. To demonſtrate that ſimilar advantages accrue from increaſing the quantity of tin in the common mixture, to render it of a harder quality than thoſe before deſcribed (43, 44) here follows the reſult of firings from four 16 prs. caſt in the royal arſenal in 1748; they had been proved as uſual; each having been fired three times at the elevation of 22½°, with powder equal to ⅔ of the weight of the ſhot at the firſt round, ⅚ at the ſecond, and a charge equal to it in weight at the third. After the proof, the bores of the four guns were perfectly ſmooth and without the leaſt flaw. They were then filled with water, and three out of the four having ſtood this new proof, were received and named *Argos*, *Hector* and *Epirus*: they were uſed ſeveral years at the battery, and gave excellent practice; for after having been fired more than 1000 times, their bores were as ſmooth as at firſt: the windage of the ſhot was ſome years in the ratio of 20 to 21, and in others of 22 to 23. The fourth gun was rejected becauſe ſome drops of water oozed through under the left trunnion; a ſmall chamber was afterwards made at the bottom of the bore of this gun, and the firſt vent being ſtopped, another was drilled correſponding to the top of the chamber; it was in 1749 fired

fired 256 times in three days from a horizontal platform; the charge was each time $4\frac{1}{4}$ lb. of war powder put into flannel cartridges; two gunners gave five ſtrokes to the wad over the powder, and three to that over the ſhot; the windage of the ſhot was as 16 to 17, the bore having been made unneceſſarily wide. The ſhot were projected in a good direction, and no alteration was viſible in the bore, or at the part where the water had oozed through.

47. To theſe ſeveral experiments may be ſubjoined a particular obſervation made in 1737, on the occaſion of an order given by the KING, to carry on practice in all the garriſons. In the CITY of VALENTIA, they made choice of a long 6 pr. which had been caſt at PAVIA in the preceding century with the arms of SPAIN and bouched, a proof of its having been frequently fired; the bore was perfectly ſtraight and ſmooth, except ſome inequalities at the bottom, which did not however hold the teeth of the ſearcher. This gun was each time loaded with $1\frac{1}{2}$ lb. of powder with the ladle, and twenty-four rounds fired daily in $3\frac{1}{2}$ hours from a horizontal platform; 60 ſhot larger than ordinary were picked out equal in weight and diameter and ſufficiently ſmooth; they ſerved during the whole ſummer, being dug out of the butt which was in the plane of the battery: the windage of the ſhot was as 35 to 36; the wads were of twiſted hay and rammed as uſual. At the cloſe of the practice for the ſeaſon, the gun was carefully examined and found after 630 rounds not to have ſuſtained the leaſt injury; the practice had been very good, ſince at the diſtance of 300 yards, a fourth at leaſt of the ſhot had ſtruck a target 3 feet in diameter, and the reſt gone very near to it.

48. From theſe premiſes may be inferred *the neceſſity of making gun-metal ſo hard and tenacious*, that *on combining theſe two phyſical qualities with the thickneſſes of metal*, artillery may be ſufficiently ſtrong, light and manageable (32), and that by judiciouſly uſing moderate charges, the advantages of firing with exactneſs and execution, and of preſerving the guns already inſiſted on in the Treatiſe on Powder, may be fully obtained.

CHAP.

## CHAP. III.

### Of the Causes of Shot striking against the Bores of Guns.

49. WHEN the metal is ſo hard as even to prevent the formation of orbicular cavities in the bore, the ſhot may ſtrike againſt the ſides of a gun that is improperly conſtructed or ſerved. In the preceding experiments the trunnions were properly placed, the bore exactly cylindrical, the wheels of the carriage of equal height and moved on an even platform, and the ſhot had been carefully ſelected: but if the bore be not perfectly ſtraight, or the motion of the gun be the leaſt irregular while the ſhot is paſſing through it, or the ſhot be not ſpherical, it muſt ſtrike the ſides whenever the wads do not cloſely confine it; and, of courſe, produce a cavity deep in proportion to the hardneſs of the metal, the actual velocity of the ſhot at the inſtant of percuſſion, and the angle of incidence under which it ſtrikes.

50. That the ſhot in paſſing along the gun may be cloſely confined by the wads may be inferred from the following obſervation.

1. The three guns (43) had defects ſufficient to occaſion every ſhot to ſtrike againſt the ſides, but this ſeldom happened during the firſt hundred rounds; and though at length the bore was ſo much damaged as to produce a violent ſhock at each diſcharge, yet there was no new appearance for ſeveral rounds.

2. In other experiments the ſhot being rough, in a ſingle round cut the bore in a right line for a conſiderable length; an effect not eaſily to be accounted for, unleſs we ſuppoſe the ſhot to be ſo cloſely confined by the wads, that it could neither roll nor change its direction. As the wads were of twiſted hay, it follows that if they were always made of a ſoft, in preference to a hard ſubſtance, they might ſometimes prevent the ſhot from damaging the bore, if its tendency to ſtrike againſt the ſides be occaſioned by the obliquity of its direction.

51. The

51. The ſhot (43) were ſometimes unconfined, and cauſed in a ſingle round cavities and other flaws, deep in proportion to their obliquity: this occurs when no wad is uſed, as in firing with red-hot ſhot, à richochet or in very quick firing in the field.

52. Guns are caſt either ſolid or with a core; which is of a cylindric form. A bar of iron, ſupported by two uprights, placed at proper diſtances from each other, is covered with well tempered clay; and when equal in diameter to the gun intended to be caſt, is heated: it frequently happens that the work-men by making the heat too violent bend the bar in the middle, particularly when it is made thin as for 4, 8 and 16 prs. In caſting guns with a core thus bent, the bore muſt be crooked; which defect it is afterwards impoſſible to remedy with the boring machine, without enlarging it beyond the proper calibre. The officers of artillery having in 1759 examined forty-ſix 8 and 16 prs. caſt with a core, found twenty-two of them bent at the diſtance of 12 to 13 diameters from the muzzle; the curvatures being in ſome $\frac{1}{12}$ of an inch, and in others $\frac{2}{12}$. By caſting guns ſolid and boring them afterwards, theſe inconveniences are avoided, and the bores are perfectly cylindric and concentric, if the machine has been accurately conſtructed.

53. One of the greateſt defects incident to a gun is, when the trunnions are placed too near to the centre of gravity. In guns of this conſtruction, the breech has a tendency to fly upwards, which renders the firing irregular and ſhortens the range, as the ſhot often ſtrikes againſt the upper part of the bore, the movement of the breech is more violent when the coins are made of elaſtic wood. There are other irregularities of movement even in guns conſtructed on the beſt principles, owing to the unequal height of the wheels of the carriages or the unevenneſs of the ground or platform.

54. Shot which are rough or not ſpherical, or that have excentric cavities are unfit for ſervice. Irregularity of figure or unevenneſs of ſurface are ſufficient to change the direction of a ſhot, as daily experience teſtifies; the obſervations already made on moving bodies will explain why internal cavities not concentric with the ſhot, muſt produce ſimilar effects. If the ſhot encounter and paſs over any ſmall extraneous body in its paſſage along the plane of the gun, its primary

mary direction will be altered, and it will purſue a freſh one communicated to it by the ſhock againſt the ſide of the gun.

## CHAP. IV.

### Of the Windage of Shot.

55. THE hardneſs of bronze and iron, and the great difficulty of making cannon ſhot perfectly ſmooth and ſpherical render it almoſt impoſſible that iron ſhot ſhould be made to fit a gun, with as much juſtneſs and preciſion as leaden bullets fit carabines: it is neceſſary therefore to allow what is called *windage*; and for that purpoſe to make the calibre of the gun greater than the diameter of the correſponding ſhot: the proportion between them muſt be ſuch as to allow for any little unevenneſs in the bore of the gun, or on the ſurface of the ſhot, and to admit of its being drawn out by the ladle, or other means, if by accident any extraneous body be lodged in the gun.

56. If fired powder followed a conſtant law, the windage could be reduced to a fixed rule (55), ſo as to guard againſt all contingencies; but as this law is ſubject to great varieties, it is neceſſary to examine how far the increaſe or decreaſe of windage contributes to the more ſudden exploſion of the powder. Among the many experiments made in the Treatiſe on Powder, to demonſtrate the exiſtence of theſe modifications, there is one (111) which ſhews how much the force of powder in muſquets is affected by the ſize of the vent; the following experiment proves that its inflammation and effects are alſo modified by the windage of the ſhot.

57. In the month of July 1759, the Commander de Vincenti, colonel of artillery, made the following experiments with two 16 prs. of the ſame weight and length, but of different calibres: the calibre of A was divided into 813 parts, and that of B into 819 of the ſame parts; the guns were fired horizontally mounted on their carriages upon platforms perfectly horizontal. The ſhot were of two kinds, and grazed on an even piece of ground about 5 feet below the axis of the gun; the ſhot of the firſt kind had the diameter = C divided into 784 of the above mentioned parts, and weighed $\frac{1}{3}$ lb. more than the proper weight; the diameter

= D

=D of the ſecond weighing $\frac{1}{6}$ more, was divided into 774 of the ſame parts. Common grained powder was uſed; the charge was 4 lb. 2 oz. put into flannel cartridges in order to collect it exactly in the ſame manner at each diſcharge: the wads were of junk; two gunners gave three ſtrokes with a rammer to the one over the powder, and two to that over the ſhot: the following table ſhews the reſult;

| | | Length of Range. | |
|---|---|---|---|
| | | Of the Gun A. | Of the Gun B. |
| | *No. of Rounds.* | *Yards.* | *Yards.* |
| With Shot of Diameter=C | 1 | *188 | 249 |
| | 2 | 198 | *197$\frac{3}{4}$ |
| | 3 | 196$\frac{3}{4}$ | 224$\frac{1}{2}$ |
| | 4 | 198$\frac{1}{4}$ | 245 |
| | 5 | *224$\frac{1}{3}$ | 248$\frac{1}{3}$ |
| | 6 | 197 | *213$\frac{1}{3}$ |
| With Shot of Diameter=D | 1 | 221$\frac{2}{3}$ | 199$\frac{1}{3}$ |
| | 2 | *193 | *213 |
| | 3 | 226$\frac{2}{3}$ | 199$\frac{2}{3}$ |
| | 4 | 223 | 199 |

After the firings, the bores were as ſmooth as before the experiment, ſo that the ranges had not been affected by the ſhot ſtriking againſt the ſides.

58. On comparing the calibres of the guns and the diameters of the ſhot, the following are in round numbers the proportions of the windage;

| With ſhot of the firſt kind. | With ſhot of the ſecond kind. |
|---|---|
| A : C : : 28 : 27 | A : D : : 20 : 19 |
| B : C : : 23 : 22 | B : D : : 18 : 17 |

On placing according to theſe proportions the number of rounds in two diſtinct columns; comprehending in the one the irregular firings marked with an aſteriſk in the preceding table, but excluding them entirely from the other; we obtain the following medium;

MEDIUM

MEDIUM OF RANGES.

| Proportion of windage. | 1ſt. Col. including the irregular firings. | 2d. Col. excluding the irregular firings. |
|---|---|---|
| | *Yards.* | *Yards.* |
| 28 : 27 | 200 | 197 |
| 23 : 22 | 233 | 247 |
| 20 : 19 | 216 | 224 |
| 18 : 17 | 203 | 199 |

From this table of compariſons it may be inferred;

1. That when theſe guns are fired as above (57) the ſhot has the greateſt velocity when the windage is in the ratio of 23 : 22.

2. That this proportion is the beſt, ſince not only the initial velocity is the greateſt, but the percuſſion of the ſhot againſt the ſides of the gun is avoided.

3. That any deviation from this proportion diminiſhes the initial velocity.

59. On applying theſe proportions (58) to a fixed diameter, as to that, for inſtance, eſtabliſhed for 16 prs. ſuppoſing the calibre of the guns be to the diameter of the ſhot, as 23 to 22, it would be found:

1. That on firing from theſe guns ſhot of a leſs diameter, viz. thoſe of $15\frac{1}{2}$ prs. the initial velocity would be diminiſhed by $\frac{1}{11}$.

2. That with ſhot of 15 prs. it would be diminiſhed nearly $\frac{1}{7}$.

3. That with ſhot of a larger diameter, viz. of $16\frac{1}{2}$ prs. the loſs of velocity would be about $\frac{1}{17}$.

60. By order of the King an invariable rule is laid down for all natures of artillery and ſhot; their calibre is preciſely determined, and directions given for aſcertaining whether new ſhot and guns have been caſt agreeably to the proportion therein eſtabliſhed; to avoid as much as poſſible the inconveniencies reſulting on ſervice from want of accuracy in this particular. There was formerly much confuſion on this ſubject; eſpecially when the guns were nearly of the ſame calibre, as 15, 16 and 17 prs. but to take away all poſſibility of miſtake in future, the calibres of our guns were fixed

fixed in 1726, at 32, 16, 8 and 4 pounders. Notwithſtanding every precaution be taken to obſerve the order in its full force, ſhot are ſometimes received which differ in diameter from the eſtabliſhed ſtandard (59). Shot of this kind may be uſed when it is not neceſſary to project them with the greateſt initial velocity; as, for inſtance, when the beſieged fire againſt the firſt works thrown up by the beſiegers, or to diſmount their artillery; and in richochet firing, or with hot ſhot.

When there is a number of ſhot of different diameters, they ſhould be put into ſeparate piles; as by uſing them indiſcriminately, it will be impoſſible to fire with preciſion or effect.

61. We learn from the hiſtory of artillery, that it has frequently been a ſubject of diſcuſſion among profeſſional men, *what is the proper degree of windage for preventing the ſhot from ſtriking againſt the ſides of the guns*, which is attributed to the want of a juſt proportion between the calibres of the guns, and the diameters of the ſhot; and after long conſideration, ſome concluded that it was owing to the allowance of windage being too great; others to its being too little.

The erroneous idea, that fired powder converted itſelf into rays of fire, which in their movement followed the law of ſolar rays, made them imagine in the laſt century that the figure of burning glaſſes was the beſt for the chambers of mortars. The ſame opinion led them to believe, that ſhot were impelled by the action of the rays in an oblique direction, if the vents were placed on the upper part of the cylinder, and to obviate this, they made ſmall chambers at the bottom of the bore: but experience has proved, that the percuſſion of the ſhot againſt the ſides of the gun, is owing neither to the windage nor to the ſituation of the vent; ſince in guns of the ſame calibre and with equal windage, ſome have ſuſtained no injury from repeated firings, while others have been unſerviceable in a few rounds.

62. The only property of windage is to facilitate the movement of a body lodged in a gun, in whatever direction it be impelled. The experiments (45, 46, 47) prove that without any regard to the proportion of windage, no damage enſues to the bore of the gun, nor is the ſhot thrown with leſs juſtneſs if the metal be ſufficiently hard, if there be no irregularity of motion at the diſcharge, inaccuracy in the bore of the gun, nor defect in the ſhot. It reſults alſo (42, 43, 44) that

that if the gun have any of the defects mentioned in the preceding chapter, the ſhot will ſtrike againſt it, whatever be the windage; but with this difference, that if the ſhot begin to move in an oblique direction, the leſs the windage and the longer the bore, the more frequent will be the ſhocks; this is too evident to need illuſtration.

63. Our theory of the inflammation and exploſion of powder deſtroys every idea of rays of fire (61), and proves that the greateſt force obtained from equal quantities of powder burned in veſſels of different figures is in that where all the powder is collected the neareſt to the vent, by which means a greater number of grains are fired; or where the fire of the firſt-generated fluid is reflected which increaſes the intenſity of the heat, and produces more fluid in a given time; or, *cæteris paribus* from a proper combination of theſe two circumſtances: hence, curvilinear chambers in mortars, particularly ſpherical ones, cauſing a quicker ignition, ſought to give longer ranges than cylindric chambers. To prove by a ſimple experiment that the property which burning mirrors have from their figure of concentrating the ſolar rays, has no effect in increaſing the force of powder fired in a veſſel of a ſimilar figure; two 16 prs. were conſtructed on purpoſe at TURIN in 1730. (Pl. 1, Fig. 3) A parabolic chamber C A D was made at the bottom C D of the bore F C D G of one of theſe guns, the axis of the parabola was in the triplicate ratio of the calibre of the gun, the vent correſponding to its focus: the other gun was of the ſame weight and length, its bore cylindric as F K L G, with the vent placed at the bottom. Theſe two guns were charged with equal quantities of powder, which exactly filled the parabolic chamber and were laid at 3° of elevation; the gun with the cylindric chamber ranged 414 yards farther than that with the parabolic chamber.

CHAP.

## CHAP. V.

### OF THE FIGURE AND LENGTH OF THE BORES OF GUNS.

64. OUR anceſtors wiſhing to derive every poſſible advantage from the uſe of artillery, fixed certain dimenſions for the conſtruction of their guns, and eſtabliſhed rules for their weights and calibres; which gave riſe to the cuſtom among the ITALIANS of diſtinguiſhing guns equal in length of bore and calibre, but differing in weight, into heavy and medium artillery.

WEIGHTS OF GUNS.

| Nature of Guns. | Heavy Guns. | | | Medium Guns. | | |
|---|---|---|---|---|---|---|
| *Pr.* | *cwt.* | *qrs.* | *lbs.* | *cwt.* | *qrs.* | *lbs.* |
| 32 | 65 | 3 | 16 | 54 | 3 | 18 |
| 16 | 37 | 2 | 2 | 32 | 0 | 3 |
| 8 | 20 | 0 | 15 | 17 | 1 | 15 |
| 4 | 10 | 3 | 26 | 9 | 0 | 19 |

The heavy artillery is intended for operations that threaten to be of long duration, as the ſieges of fortified towns well provided with troops and ſtores.

The medium artillery is deſtined to march with armies, and be uſed in affairs that muſt ſoon be terminated; as general or partial engagements, attacks of poſts or intrenchments, aſſaults of towns, houſes or villages.

65. The ordinary figure of the bores of guns is cylindric; the length contributes to a certain point to increaſe the initial velocity of the ſhot, and give longer and juſter ranges. (Treatiſe on Powder). The length of the battering guns now in uſe, is not ſufficient to project the ſhot with the greateſt initial velocity; but if they were made longer and larger charges uſed, they would become extremely unwieldy: moreover, experience has proved that theſe very long guns do not throw their ſhot with juſtneſs; and the ſhocks againſt their ſides, particularly near the muzzle, are more frequent and violent when charged with modern powder, which is

conſiderably ſtronger than that uſed formerly: the charges then being neceſſarily larger, occupied a greater ſpace in the length of the bore Cannon not to be injured by long firing, and to project their ſhot with juſtneſs (9), ſhould be ſhorter than the guns anciently were: but exceſs on this ſide is to be equally guarded againſt, as on the other; for ſhort guns of large calibre ſoon damage the embrazures; the initial velocity of the ſhot, the length of range, and effects on the object are diminiſhed; and there is more probability of error in pointing ſhort guns than long ones.

66. After the various opinions that have at different times been ſuggeſted on the proper length of guns, intended to fire through embrazures, all nations ſeem to have adopted with little variation the following proportion:

| Nature of Guns. | | Length of Bore. | |
|---|---|---|---|
| *Pr.* | | *Feet.* | *Inches.* |
| 32 | — | 10 | 0 |
| 16 | — | 9 | 6 |
| 8 | — | 8 | 6 |
| 4 | — | 6 | 9 |

This is the common length: when longer they are termed *long*, and when ſhorter, *ſhort guns*. (Pl. 1, Fig. 2.) Set off on the line B F of a gun of any calibre three diameters of the bore, for the charging cylinder; divide the remainder C F into four equal parts at H, G, K, and make F L = F K: B L may be then conſidered as the greateſt length that guns ſhould be ever made of, to avoid the inconveniences pointed out in the preceding paragraph: and if from B F, K F be taken, the remainder B K is the leaſt length for guns with cylindric bores.

67. When 32, 16, 8 and 4 prs. (66) are loaded with the uſual ſervice charges of powder and rammed with equal force, the initial velocities will in ſhort ranges increaſe in proportion as the calibres diminiſh; but in long ranges, the ſhot from the reſiſtance of the air will be projected farther from guns of large than of ſmall calibre, in proportion to the diſtance; as appears by the following experiments. The guns were loaded as above directed, and the ſhot ſeverally fell on three ſpots below the plane of the battery.

NUMBER

NUMBER OF YARDS BELOW THE PLANE OF THE BATTERY.

| Nature of Guns. | 1ſt. 1 Yard. | 2d. 30 Yards. | 3d. 190 Yards. |
|---|---|---|---|
| Pr. | | Length of Ranges. | |
| 32 | 219 | 1045 | 2023 |
| 16 | 229 | 1056 | 1961 |
| 8 | 233 | 1050 | 1835 |
| 4 | 238 | 1003 | 1703 |

From the experiments made in the Treatiſe on Powder, (101) and others related by ſome FRENCH Authors to have been made at DUNKIRK; it reſults that *guns of the largeſt calibre give the longeſt ranges.* The experiments at DUNKIRK were carried on with 24, 16, 12, 8 and 4 prs. French guns laid at 45° of elevation; the charges of powder were equal to $\frac{2}{7}$ of the weight of the ſhot; and the length of the guns was 11 feet.

| Nature of French Guns. | | | Length of Range. |
|---|---|---|---|
| Pr. | | | Yards. |
| 24 | — | — | 4817 |
| 16 | — | — | 4324 |
| 12 | — | — | 4002 |
| 8 | — | — | 3552 |
| 4 | — | — | 3254 |

68. Hence it may be inferred that common guns of large calibre will range farther than long guns of ſmall calibre; the latter are principally uſefull againſt objects not too diſtant or ſolid: of this kind are long 8 and 4 prs. which are placed to great advantage in fortreſſes ſituated on plains or gentle eminences, to keep the enemy in reſpect and command the environs of the place; as fewer men are required to work them, and much ammunition is ſaved.

69. Long guns of large calibre ſhould only be uſed in caſes of neceſſity; ſome 32 prs. for inſtance, may be placed in works ſituated on mountains to moleſt the beſiegers, when they can form their magazines and park of artillery out of the reach of ſmaller guns; and in maritime towns to keep

the enemy's veſſels at a diſtance. Formerly inſtead of long guns, they uſed guns of the common length with ſpherical chambers at the bottom of the bore, larger in diameter than the calibre of the gun; they ſometimes ranged farther than long guns; but theſe chambers ſhould be reprobated on every other occaſion, from the great difficulty of loading them: they muſt be very ſtrongly reinforced, the trunnions placed in ſuch a manner as to prevent any irregular movement at the diſcharge, and the carriages made to admit a higher elevation than thoſe of the common conſtruction.

70. Short guns of large calibre and cylindric bore may be planted on works, where it is neceſſary to have guns, but not room ſufficient for the recoil and management of longer guns: but as they are deſtructive to the embrazures, howitzers or *carronades* are preferable to them, if from the point where they are placed, it is only intended to fire caſe ſhot, for they do not damage the embrazures ſo much as ſhort guns; their charges being leſs in proportion to their calibre, and the diameter of the chamber leſs than the diameter of the bore.

71. An army deſtined to act in a champaign country ſhould have a train of artillery (64) compoſed of medium 8 and 16 pounders. In caſe it may be neceſſary during the campaign to occupy a poſt or attack a town ſurrounded with occaſional works or ſingle walls, ſome guns of large calibre ſhould be depoſited in a ſecure place within reach of the army. The trunnions of medium guns ſhould be placed nearer the muzzle, which would render them firmer on their carriages and more regular in their movements.

72. When the ſcene of action lies in a mountainous country, where from the badneſs of the roads the tranſport of carriages is almoſt impracticable; a few pieces of iron ordnance may be placed in the poſts of the greateſt importance; and the train of artillery left in the rear, till local circumſtances or the future operations of the campaign make it neceſſary to bring it up. Should there be a neceſſity of having ſome ſhort guns (66) for opening a paſſage through defiles, &c. the diameter of the chamber ſhould never exceed the calibre of the gun, as they are very uncertain in their effects.

In the laſt century very ſhort and light guns of different natures and leſs in calibre than 4 prs. were invented for accompanying troops through rough and difficult countries; but experience has ſhewn that they do not produce the advantages

advantages their projectors promiſed; and that, independent of a heavy and uſeleſs expence, they cauſe much embarraſſment in the diſpoſition and movements of an army.

73. Guns caſt of iron of a very tenacious quality may be uſed in places of ſmall importance, field works and thoſe parts of permanent fortifications that cannot from their ſituation be obliged to maintain a very long cannonade: they are generally two diameters ſhorter than braſs guns of the ſame calibre, it having been found by experience that when very long the muzzle is ſoon injured; wherefore *there are no long guns of iron.* Iron guns for ſhips of war are made nearly of the length of ſhort braſs guns (66), for the facility of loading them within the port-holes to ſhelter the ſeamen from the enemy's muſquetry; for though their initial velocity be leſs, that is looked upon as a matter of no great moment, ſince ſhips can approach near enough to each other to make the ſhot penetrate the ſides.

74. In determining the length of the barrels of muſquets, it was not conſidered which would impel the bullet with the greateſt initial velocity, but which was beſt adapted to the different methods of fighting: for muſquets that are too long or too ſhort are equally inconvenient, and the ſoldier ſhould *ever be aſſured of the goodneſs and effect of his fire-arm* (7). Dragoons being deſtined to act occaſionally, either as infantry or cavalry, are armed nearly in the ſame manner as infantry; while that the carabine and piſtol of the horſe being of no ſervice on a charge, but only on detachments or ſkirmiſhes, the facility and eaſe of managing them on horſeback are chiefly attended to.

75. Mortars in the firſt year that ſucceeded to their invention, were conſtructed of different calibres, figures, and dimenſions, according to the various ſervices for which they were deſigned: the bore of the largeſt was 20 inches in diameter, that of the ſmalleſt $5\frac{1}{2}$ inches; the latter were called royal mortars. The largeſt mortars at preſent do not exceed 15 inches; thoſe of 13 inches are moſt commonly uſed.

76. From the interior figure of mortars, the elaſtic fluid generated in the chamber is dilated on paſſing into the chaſe; its preſſure againſt the ſhell is ſtill ſufficient to give it a proper velocity, unleſs the charge be too ſmall; as is ſeen in carronades and howitzers, which in reſpect to their interior figure may be compared to mortars with cylindric chambers. The irregularities of ranges of mortars fired under a larger angle

than 15° may be owing to the bombardiers that load the mortar; or to the recoil not being in the direction of the range: the too great length of the chaſe is the cauſe of both theſe circumſtances; for before the ſhell can quit the mortar, it has recoiled a ſpace equal to half the difference between the diameters of the mortar and of the ſhell; the direction of the latter is then altered by ſtrikingagainſt the mortar, which is frequently much damaged.

77. The chaſe ſhould be ſo ſhort that the bombardier may eaſily adjuſt the powder and the ſhell; and that the ſhell in quitting the mortar may not be able to ſtrike againſt it, and alter its recoil. The chaſe of the largeſt mortars ſhould be a diameter and half of the bore in length, which would greatly facilitate the loading: upon this principle the chaſe of ſmall mortars might be longer: but as the ſtriking of the ſhell againſt the mortar depends on the difference between their diameters, the length of the chaſe muſt in all mortars be proportionate to the diameter of the bore, the proper degree of windage having been previouſly determined.

78. From the moſt accurate experiments that have been hitherto made, it appears that mortars will be of the beſt proportion, when the length of the chaſe does not exceed a diameter and half of the bore, and when the windage is 23: 22. If the windage be leſſened, the chaſe muſt alſo be ſhortened, as in mortars uſed in proving powder; where very little windage being allowed, the length of the chaſe is only a diameter and a quarter of the bore.

79. The beſt length of the chaſe in mortars, for facilitating the operations of the bombardiers and preventing the ſhock of the ſhell, and the obliquity of the recoil being determined; it is neceſſary to have recourſe to expedients to give the greateſt initial velocity to the ſhells, which is often required on ſervice without lengthening the chaſe: this is effected:

1. By conſtructing the chamber of ſuch a figure that the powder being collected cloſe to the vent, more of the fluid may be generated in equal times: the ſpherical figure is the beſt for anſwering this purpoſe, as has been explained in the Treatiſe on Powder.

2. By oppoſing a great reſiſtance to the exploſion of the powder, without increaſing the weight of the ſhell, by which means more of the elaſtic fluid will be generated before it is in motion; this reſiſtance may be augmented by placing a tompion of wood over the earth that

that is rammed upon the powder, and by preſſing earth cloſe round the tompion and the ſhell; the initial velocity will be thus increaſed.

3. By increaſing the ſize of the chamber.

80. Stone mortars are uſed for throwing troops, workmen, &c. at ſieges into confuſion: the chamber is in form of a troncated cone, whoſe leaſt baſe is towards the vent; they are fired with ſmall quantities of powder, as with large charges the ſtones would ſpread ſo much that few or none would have effect. Their diameter ſhould not be leſs than 15 inches, nor the chaſe leſs than a diameter and a half in length, that it may contain a ſufficient quantity of ſtones: by increaſing the diameter and length of the chaſe, they would contain more ſtones, and conſequently be more deſtructive; but then from their weight they would be very difficult to tranſport.

## CHAP. VI.

### Of the Thickness of Metal in Fire-arms.

81. THERE are two extremes to be equally avoided in determining the thickneſſes of metal in fire-arms, the one is, making them too thin and light; the other, too ſtrong and heavy: the danger ariſing from the firſt is too obvious to need inſiſting on; the ſecond is comprized within certain limits. The metal proportionally diſtributed throughout the whole length of the piece, ought to be capable of reſiſting the forces which at each point tend to burſt it; and of ſuch a weight as to prevent any irregularity in the motion of the ſhot, that would materially affect the juſtneſs of the firing (9): we will endeavour to aſcertain theſe limits.

82. No abſolute and general rule can be laid down for the thickneſs of metal in guns, ſince ſeveral phyſical points are involved in the problem. In a gun of a given calibre, the thickneſſes proper to reſiſt the preſſure of the fluid, may be known by firing it very ſtrongly reinforced ſeveral times with the ſame charge; then thinning the metal and firing it again with the ſame charge; and thus ſucceſſively diminiſhing the thickneſſes, till they be ſo reduced that the piece burſt at once in every point of its length. Such experiments cannot be

concluſive in all caſes, though made with the utmoſt accuracy; as there may be defects in the maſs of metal, for which allowance cannot be made. To avoid ſuch a tedious proceſs, the ſcale of preſſures of the fluid againſt the ſhot may be conſtructed; this method of reſolving the problem is the moſt eaſy and ſimple: but the greater the diſtance of the point where the thickneſs of metal is determined from the place where the ſhot is lodged in the gun, the leſs exact will be the ſolution.

83. To enable guns to reſiſt the preſſure of the fluid, the thickneſſes of metal muſt be determined from the ſcale of preſſures. With reſpect to heavy artillery (64) ſeveral rounds ſhould be fired from three or four guns, differing in length but of the ſame calibre as the guns whoſe thickneſſes are ſought, with the larger ſervice charges; the wads rammed down with more force than with the medium charge; and the initial velocity of each ſhot meaſured. (Treatiſe on Powder.) To conſtruct a ſcale for eſtimating the proper thickneſſes of medium artillery (71), the largeſt charges ſhould be uſed that the guns will bear, and the wads rammed with the ſame force as the wads of guns more reinforced and loaded with the common charge: it is eſſential to obſerve this, as from the different reſiſtance of the wads, a conſiderable difference ariſes in the ordinate that expreſſes the greateſt preſſure of the elaſtic fluid, and ſucceſſively in the other ordinates; as may be inferred from the fourth chapter of the Treatiſe on Powder, where the modifications of the elaſtic fluid in the cylindric bores of guns are conſidered. The initial velocities of the ſhot being meaſured, and a line drawn to expreſs the ſcale of velocities in certain ſpaces, the ſcale of correſponding preſſures may be found from this line by the method directed in the treatiſe on moving bodies. It ſhould be remarked that the velocities of ſhot from guns of large calibre fired with large charges, are produced by the preſſure and impulſion of the elaſtic fluid, which, generated at the bottom of the bore, acts with ſuch force on the ſhot (37) as to communicate to it a conſtant velocity, which the ſecond wad however ſtrongly it may be rammed cannot deſtroy. The ſcale ſhould then be parallel to the axis of the gun; and its diſtance from it equal to a right line drawn perpendicularly to the axis, expreſſing the conſtant velocity produced by the impulſion of the fluid.

84. This

84. This being premiſed; let a gun (Pl. 1, Fig. 4) A B C D be caſt of the ſame metal, calibre, and length as thoſe of which the thickneſſes are ſought, and its dimenſions determined by a right line C D drawn obliquely to A B, ſo that the thickneſs A C of the breech may reſiſt the preſſure of the fluid; the thickneſs B D at the muzzle will be much leſs. Suppoſe this gun (83) burſt at the firſt round in any point between A and B, as at G; ſhould it burſt in ſeveral places at once, moſt attention ſhould be paid to the opening next the breech. Let F G where the metal yields to the preſſure of the fluid be thickened in the proportion of the tenacity of the bronze, heated by firing as much as it can be on ſervice (35) to its tenacity when cold, and call it $= m$; then $m$ expreſſes the proper thickneſs of metal at the point G of the length A B. It is eſſential to remark, that the fracture in G was occaſioned ſolely by the preſſure of the fluid, and not by the percuſſion of the ſhot againſt the ſides of the gun, nor by any defect in the metal; as may be known by examination.

85. Let H E repreſent the bore of a gun, whoſe thickneſſes of metal are ſought; (Pl. 2, Fig. 5) draw the ſcale L O Q R (83) of the preſſures of the fluid deduced from the rectangular ordinates; make E P equal A G (Pl. 1, Fig. 4) and P T equal to $m$; then if O P be the greateſt ordinate of the ſcale L O Q R, from the point T draw T Y parallel to P E for the thickneſs of metal from P to E; in order to find them from P to H make the following proportions; P O : N Q :: P T : N V, and P O : H R :: P T : H X, draw a line through the points T V X; then Y T V X will be the ſcale of thickneſſes ſought. But if K L be the greateſt ordinate, find K S a fourth proportional to P Q, T P, K L; and from the point S draw S Z parallel to K E, in order to have the thickneſſes from K to E; then Z S T V X will be the ſcale of thickneſſes in the whole length E H of the gun.

86. To apply this theory to a particular caſe; (Pl. 2, Fig. 5) let a 32 pr. be charged with 13 lb. 2 oz. of fine war powder, and the wads rammed ſo as not to diminiſh the volume of the powder. Let the proportion of tin in the gun-metal be $\frac{1}{6}$ and the gun be ſo heated as to fire powder; its greateſt thickneſs in a ſtate of equilibrium will be K S. If the gun be fired under the moſt favourable circumſtances to the inflammation of the powder, that is, $n = 1200$ (33) the greateſt thickneſs K S ought to be $\frac{1}{14}$ of the diameter

diameter of the bore, and the leaſt thickneſs H X between $\frac{1}{3}$ and $\frac{2}{3}$ of K S. If the proportion of tin be $\frac{1}{8}$ the greateſt thickneſs K S ſhould be $\frac{25}{32}$ of the diameter of the bore and H X $\frac{1}{3}$ or $\frac{2}{3}$ of $\frac{25}{32}$.

87. the following conſequence may be drawn from a conſideration of the theorem 9962 $n r = m q$ (33):

1. That in two guns of equal calibre caſt from a different compoſition, fired with equal charges of powder, and wadded in the ſame manner; if $r$ and $n$ be conſtant quantities, the thickneſſes $= m$ at points equally diſtant from the bottom of the bore ought to be in the reciprocal ratio of the tenacity $= q$ of the different metals.

2. That in the ſame gun on altering the charge, as the preſſures of the different points will differ from thoſe produced by the firſt charge, the correſponding thickneſſes ſhould be in the ratio of the ſecond preſſures.

3. That in two guns of different calibres, if the tenacity $= q$ and the preſſure $= n$ in points equally diſtant from the bottom of the bore, the ſame ordinate will expreſs both; the thickneſſes $= m$ of the two guns in the ſame point will be proportional to the radii $= r$ and thence to their calibres.

88. If the thickneſſes of a gun correſpond with certain determined circumſtances; (Pl. 2, Fig. 6) as for example, if A B C D be a 32 pr. of which the thickneſſes H H, K K, A L are as before expreſſed (86) and it be wiſhed to determine in a gun D C F G of a different calibre, the correſponding thickneſſes M M, N N, G P, the problem may be eaſily ſolved by the concluſions drawn in the laſt paragraph, without having recourſe to experiment: other problems alſo that are connected with the modifications of the fluid may be ſolved by the ſame method.

89. The rules here laid down for determining the thickneſſes of metal in guns of cylindric bores would anſwer for every poſſible caſe, if the ſhot never ſtruck the ſides: but if in a gun thus proportioned, the ſhot ſhould ſtrike the ſides, the metal would yield and the gun burſt. Theſe percuſſions of the ſhot produce in braſs guns two different effects: they cauſe hollows in the inſide, which are always perceptible whatever be the ſize of the gun; but the harder the metal, the leſs impreſſion the ſhot makes: thus they cannot be avoided by adding to the thickneſs of metal, but may by increaſing its hardneſs; but what is thus gained in hardneſs, is loſt in tenacity.

tenacity. The ſecond effect produced by the ſhot is the bulging or external ſwelling of the metal, the cracking and conſequent ruin of the pieces: this depends on the combination of tenacity with the thickneſs of metal; and to prevent it, the thickneſſes muſt be augmented. In iron guns, when the percuſſions of the ſhot are very violent, the piece burſts without any hollow being found in the bore, or any ſwelling on the outſide: wherefore, if the tenacity of iron could be ſufficiently increaſed without prejudice to its hardneſs, it would be preferable to any other metal.

90. To determine the thickneſſes from the point T, (Pl. 2, Fig. 7) where the ſhot is lodged, to the muzzle of the gun, and prevent the metal from bulging; it is neceſſary to have the ſcale T L M of the velocities in the ſpaces T P, T C. The force with which the ſhot ſtrikes the gun in any point as in V, is expreſſed by the product of the weight of the ſhot, multiplied by the correſponding velocity P L, and by the right ſine of the angle of incidence K V A. If theſe ſhocks proceed from a conſtant cauſe, viz. an orbicular cavity in T, the point that the ſhot ſtrikes is farther diſtant from T as the cavity is leſs deep, and the angle of incidence K V A becomes leſs. But if the ſhocks proceed from any adventitious cauſe, which alters the direction of the ſhot, and gives an irregular motion to the gun (53) then the angle of incidence may be greater, and the force at the different points V will be proportional to the correſponding velocity P L. That the thickneſs of a gun may be proportionate to the greateſt ſhocks it can receive, experiments ſhould be made with pieces of metal of the ſame quality as that of which the gun is caſt; and the proper thickneſs at the muzzle to prevent its burſting or yielding in any manner to the ſhot determined. Suppoſe this thickneſs = B N, then C M : P L :: B N : V Q; the line H Q N will be the ſcale of thickneſſes ſought, and will cut in the point R the ſcale S F R G D of the reſiſtance to the preſſures of the fluid (88, 89): therefore the line S F R Q N will determine the thickneſſes throughout the whole length of the piece, capable of reſiſting the forces that tend to burſt it.

91. In thus proportioning the thickneſſes of metal to the force of the moſt violent ſhocks, the gun would be thicker at the muzzle than at the breech, and of courſe extremely unweildy. But as theſe direct ſhocks can only ariſe from ſome very uncommon cauſe, and the accelerated preſſures of

of the fluid againſt the ſhot, act in the direction of the axis; the thickneſſes determined by the line R Q N, may be much diminiſhed without any riſque of burſting the gun. The following obſervations made on more than 100 guns that were rendered unſerviceable by the ſhocks of the ſhot, may be adduced in order to aſcertain ſome limits for this proportion. Theſe guns in reſpect to thickneſs of metal, were of three kinds: the firſt were determined by a ſcale made from the diameter of the bore; the thickneſs at the breach was one diameter; at the end of the firſt reinforce $\frac{15}{16}$; at the beginning of the ſecond reinforce $\frac{14}{16}$; at the end of the ſecond reinforce $\frac{13}{16}$; at the beginning of the chaſe $\frac{12}{16}$; and at the muzzle $\frac{8}{16}$. The guns of the ſecond kind were in the ſame proportion, but the ſcale formed from the diameter of the ſhot, ſo that they were not ſo thick as the firſt kind. The third kind was as the ſecond, proportioned from the diameter of the ſhot from the breech to the firſt reinforce; but, at the beginning of the chaſe was only $\frac{11}{16}$ of the diameter, and at the muzzle $\frac{6}{16}$. The leaſt thickneſs of the ſwell of metal at the muzzle was, including the ornaments, $\frac{3}{4}$ of its diameter in the three kinds of guns. It was obſerved;

1. That in the guns of the firſt kind, a very violent ſhock cauſed neither crack nor bulge in whatſoever part it ſtruck: the force and direction of the ſhock being gathered from the form and depth of the cavity.

2. That in the guns of the ſecond kind, the ſhot having ſtruck violently between the half of the chaſe and the muzzle, the metal bulged out; and at the ſucceeding round, the muzzle dropped.

3. In the guns of the third kind, bulges and cracks were obſerved at about $\frac{2}{3}$ of the length of the chaſe; and though the exterior of the muzzle did not appear the leaſt altered; yet, at the next violent ſhock it dropped.

92. From the preceding obſervations (86) it may be concluded; that if the gun from A to G (Pl. 3, Fig. 8) has its thickneſſes A C, G D $= \frac{14}{16}$ of the diameter of the bore, and B F $= \frac{8}{16}$; the right line D F, will expreſs the thickneſſes neceſſary to reſiſt the forces that tend to burſt the gun, viz. the action of the fluid at N, and every other point of the length of the bore, and the moſt violent ſhocks from the ſhot; provided that the ſwell of metal H at the muzzle

zle be not leſs than $\frac{1}{16}$, and be for greater ſecurity connected with the muzzle aſtragal, by the convex line H L K. Gun-metal not being ſufficiently hard to prevent the ſhot from making impreſſion when they ſtrike with great force againſt any part of the chaſe, it would be better, as a means of obviating this inconvenience in ſome meaſure, if the moulds were placed in a different poſition from what they are at preſent, with the breech up and the muzzle down, as in caſting mortars: by this method the metal at the chaſe would be denſer than at the breech, and of courſe more hard and tenacious. This with proper precautions, may be done whether the guns be caſt ſolid or with a core.

93. Guns conſtructed on theſe principles (92) tho' ſufficiently ſtrong are defective in two points: they are too light, and conſequently their motion being irregular, it is impoſſible to fire with juſtneſs; and there is a neceſſity for placing the trunnions too near the muzzle, that the motion of the breech may not be ſo violent as to render abortive every attempt to hit the object: from the latter circumſtance alſo, they cannot enter far enough into the embrazures; which are very ſoon deſtroyed by the exploſion of the powder. The beſt remedy for theſe defects is to reinforce the gun particularly at the breech, according to the proportions laid down in the firſt book of artillery: it will then be ſufficiently heavy to prevent any irregularity even with the largeſt charges; the trunnions may be placed nearer the breech, and the muzzle will enter farther into the embrazures.

94. The dimenſions (7, 8, 9,) for the body of the piece being thus determined; the proper poſition of the trunnions, caſcable, baſe-ring and dolphins muſt be aſcertained. The trunnions ſhould be placed between the centre of gravity and the muzzle, that the gun may be rather heavier at the breech, without rendering it difficult for two gunners to raiſe it with their handſpikes, for the purpoſe of laying it, and that it may enter far enough into the embrazure; their diameter is equal to one calibre. The poſition of the dolphins ſhould be ſuch, that when the gun is ſuſpended by them, the breech may preponderate a little, that by taking hold of the caſcable it may be the more eaſily managed. It is cuſtomary to engrave on the upper part of the gun, the arms of the king and the maſter general of the ordnance, with inſcriptions, trophies, &c. which obliges the founders to raiſe the baſe-ring, and the ſwell of metal at the muzzle higher

higher than the ornaments, that the viſual ray may paſs over them. If the baſe ring be higher than the ſwell of metal at the muzzle, the viſual ray will cut at a ſmall diſtance the axis of the gun produced; this will make it eaſy to point at diſtant objects that are not much elevated above the plane of the gun, when there are no higher objects behind them to fix the eye, as often happens in the attack of citadels. The junction of the muzzle to the neck, will conſiderably reinforce the gun at that part. The metal at the bottom of the bore is much thicker than at the other parts, the better to reſiſt the exploſion: the formula (Philoſ. Inſtit.) for meaſuring the reſiſtance of the baſes of cylinders, will exactly aſcertain the quantum of this exceſs.

95. A gun mounted on its carriage is ſupported by the trunnions, and reſiſts the exploſive force of the powder by the tenacity of the metal of which it is caſt: the momentum of this force is expreſſed by the product of the weight of this part of the gun, into the diſtance from the centre of gravity to the point of ſupport. On applying this principle to our theory (Philoſ. Inſtit. 233) it will appear that the metal heated as much as it can be on ſervice is greatly ſuperior in tenacity to the different forces that tend to bend or burſt it.

Some guns that had been rendered unſerviceable at the attack of SAVONA, were ordered to be brought to PIEDMONT: for the facility of tranſport they were ſawed in pieces, which gave an opportunity, previous to the operation, of aſcertaining experimentally the truth of the foregoing principle: A 32 pr. conſtructed on the ſame proportions as guns of the firſt kind (91) was fixed by its trunnions upon a rock; the breech was ſolidly built into a wall, ſo that from the trunnions to the muzzle it was ſuſpended in the air; the part not fixed in the wall was heated by a large wood fire, till a ſtick on touching it ſmoked, and inſtantly blazed; a much greater degree of heat than guns ever acquire in the heavieſt and longeſt cannonades. The gun being thus heated, two workmen gave more than 100 ſtrokes with a ſledge hammer on the ſwell of metal at the muzzle, with all their might, without doing it the leaſt injury: from this experiment where the force employed to overcome the tenacity of the metal was ſo great, we may infer that the chaſe is capable of ſufficient reſiſtance.

96. From

96. From theſe premiſes, the following concluſions may be drawn with regard to heavy artillery.

1. That long guns ought to be caſt of a harder metal and more reinforced from the middle of the chaſe to the muzzle, as in that part guns of this nature are moſt expoſed to be ſtruck by the ſhot.

2. That ſhort guns intended to be fired with large charges ſhould be reinforced as much as guns of the common length, ſince they have equal forces to reſiſt: for example, if A T be the length of a ſhort gun that has the ſame thickneſs of metal as the common gun A B; (Pl. 3, Fig. 8) ſuppoſing A B to be ſawed aſunder in T, the ſwell of metal ſhould be placed at T, and the trunnions fixed nearer to the breech, to make it preponderate.

3. If the medium charge be the largeſt ever uſed for theſe guns, and be rammed in the common method, the thickneſs A C may be $\frac{1}{16}$ of the calibre, and the other thickneſſes diminiſhed from the breech to the muzzle in the proportion of common guns.

4. If theſe ſhort guns are only intended for firing caſe-ſhot without wadding, the calibres may be increaſed and the thickneſſes conſiderably diminiſhed. A cylindric chamber made at the bottom of the bore, will leſſen the charge of powder and of courſe preſerve the embrazures.

97. If guns (71, 72) containing $\frac{1}{8}$ of tin only be fired with the medium charge, and the firſt wad receive five and the ſecond three ſtrokes from two gunners; the thickneſſes of metal may be ſo proportioned that the weight of medium guns may be the ſame as before expreſſed (64); and in ſhort guns of cylindric bores (66, 72, 96, No. 3) they may be diminiſhed, if the charges be leſſened or the wads compreſſed with leſs force.

98. In ſhort guns and even in medium guns, (6, 7, 8, 9) the trunnions ſhould be placed nearer to the muzzle as they are never intended to fire through embrazures: if this be deemed inexpedient, ſome method may be deviſed of fixing the breech to the carriage. Many inventions have been propoſed for this purpoſe, of which the artilleriſt may conceive an idea from the models in the royal ſchools. By placing the trunnions nearer to the breech it will preponderate leſs, and the gun be more eaſily depreſſed or elevated.

elevated. The viſual ray ſhould paſs over the ornaments and interſect the axis of the piece produced not far from the muzzle (94). From the conſtruction of theſe ſhort guns, there is a very great difference between the diameters of the baſe-ring and muzzle, which being conſidered by ſome artilleriſts as a defect, a projection was made upon the baſe-ring of ſome guns caſt in the laſt century, and pierced with holes; which gave the gunner a free and uninterrupted view along the gun, and enabled him to lay it with preciſion to very diſtant objects: others have imagined a moveable inſtrument pierced with holes, the baſe reſting vertically upon the baſe ring, by means of which the gun could be laid at different elevations as the viſual ray paſſed through the holes along the gun towards the object; other holes were made horizontally to correct the direction in caſe the preceding one was wrong: but as artilleriſts may ſupply the want of theſe inſtruments in a very ſimple and eaſy manner, it is unneceſſary to dwell any longer on the ſubject.

99. The thickneſſes of metal in mortars are the ſame *as were* uſed by our anceſtors for a long ſeries of years. The theorem 9962 $nr^2 \div 2rm + m^2 \times q$ will ſhew that the thickneſs at the breech in mortars with ſpherical chambers is ſufficient to reſiſt the ſtrongeſt preſſures of the fluid, when the chamber is filled with fine war powder confined by a tompion of wood, and the ſhell ſurrounded with earth ſtrongly compreſſed. The theorem (Philoſ. Inſtit.) for the baſes of cylinders will ſerve for mortars with cylindric chambers, but as the modern powder is much ſtronger than that uſed in the laſt century, the thickneſſes may be increaſed $\frac{1}{6}$, and then the mortars will be ſufficiently ſtrong for every purpoſe.

100. In mortars fired with the largeſt charges, the elaſtic fluid generated in the chamber is conſiderably dilated on paſſing into the chaſe; the ſcale of preſſures therefore will very ſuddenly approach the axis of the mortar; whence no damage can enſueif the thickneſſes have been properly proportioned. Mortars caſt on theſe proportions, of metal containing $\frac{1}{6}$ of tin, reſiſt the preſſure of the fluid, and every other force that tends to deſtroy them, as the impulſion of the fluid, and the percuſſion of the ſhell: but if the chaſe be not united to the breech by a conſiderable thickneſs of metal, it will be broken off, or at leaſt incurvated. If the metal contain $\frac{1}{6}$ of tin, the impreſſion of the ſhells will be leſs; but the thickneſs muſt be increaſed.

101. Mortars

101. Mortars are moreover liable to an accident that defeats every good purpoſe expected from the uſe of them; viz. the burſting of the ſhell in the mortar, or immediately on quitting it. This may proceed from a defect in the fuſe, the negligence of the bombardiers in loading the mortar, or not priming it before the fuſe is ſet fire to, or from a hole in the ſhell through which the fire from the exploſion communicates with the powder. When from either of theſe cauſes it burſts in the mortar, it generally renders it unfit for further ſervice. Increaſing the thickneſs of metal in mortars, whatever be the motive, will be always advantageous; provided they are not too unweildy: ſince in all fire-arms ſolidity adds to the juſtneſs of execution.

102. The trunnions if equal in diameter to the ſemi-diameter of the mortar will be ſufficiently ſtrong: they ſhould be let into the bed throughout the whole length, or at leaſt the points of ſupport ſhould be near the breech of the mortar; for when they are ſupported only by the extremities, they are liable to bend and break, as has frequently happened.

103. Mortars are made of different diameters according to the uſes for which they are deſigned; thoſe from 15 to 20 inches, are for throwing ſtones to retard the progreſs of the beſiegers, and are never fired to a greater diſtance than 350 yards, as in longer ranges, the ſtones are too much ſcattered to do execution; their chambers therefore are in form of a troncated cone, with the greateſt baſe towards the muzzle and contain but little powder. This mortar having no great effort to ſuſtain, may be leſs reinforced: the thickneſſes allotted for ſtone mortars will anſwer for every purpoſe in which it is uſed, as in throwing fire balls, carcaſſes, &c.

104. Thirteen inch mortars, with chambers ſpherical, elliptical, or in form of a pear, are deſigned for throwing ſhells to deſtroy magazines and other military edifices. If it be wiſhed by increaſing the range to add to the effects of the ſhell by the height of the fall, the ſpherical chamber is the beſt; but then it is neceſſary to increaſe the thickneſſes of metal, to inſure proper reſiſtance and ſolidity. In the laſt century, 20 inch mortars were made with curvilinear chambers to fire from very great diſtances, that the ſhells might fall with irreſiſtible force on magazines and other buildings; but their exceſſive weight has cauſed them to be diſuſed in land ſervice: even 15 inch mortars are very difficult to work

upon batteries, and the ſhell is very unweildy; they are principally uſed at ſea in bomb-ketches, for the purpoſe of bombarding maritime places from great diſtances.

105. Ten inch mortars are very uſeful in attack and defence, for diſmounting the enemies cannon and demoliſhing their works and buildings; they are not expenſive and eaſily worked: the beſt form for their chamber is cylindric; it being of great importance that the firing from them ſhould be very exact, they ſhould be well reinforced to enable them to reſiſt the ſhock of the ſhell and increaſe the ſolidity. Mortars have been likewiſe conſtructed of $5\frac{1}{2}$ and $4\frac{2}{5}$ inches in calibre; they range but a ſhort diſtance and require the greateſt accuracy and preciſion. It may be inferred from theſe remarks that mortars cannot be made lighter without conſiderably diminiſhing their effects.

## CHAP VII.

### Of Casting Artillery.

106. THERE muſt be a combination of ſeveral circumſtances to inſure ſucceſs in caſting artillery: unleſs the metal be of good quality and properly proportioned, the guns may be defective, perhaps uſeleſs; and though much depends on ſcience and experience, yet chance has frequently no ſmall ſhare in the event. The principal motive for examining and ſubjecting guns and mortars to various proofs before they are declared fit for ſervice, is the uncertainty under which the moſt able founders have at all times laboured on this head; and among the ſeveral experiments made to aſcertain their goodneſs, there are ſome which would be highly abſurd, were they not intended for the detection of artifice or ignorance.

107. To ſucceed in caſting guns and mortars there muſt be:

1. A perfect connection between the metallic particles; which depends on the degree of heat and fuſion when the metal is run from the furnace into the moulds.
2. An exact mixture of the ſeveral metals.
3. A moſt accurate preparation of the moulds.
4. No vacuity in any part of the bore of the gun, that may render it dangerous to the men that ſerve it.

108. In

108. In diſpoſing the metals in the furnace, the firſt ſtep is to weigh them ſeparately, in the proportions previouſly determined and place them near the furnace. When it has been heated for four or five hours, it is cleaned and ſome cakes of copper put in at the mouth; which being fluxed ſpread over the ſurface of the hearth; the reſt of the copper is then gradually introduced till the whole be fuſed; and to facilitate it ſome tin is thrown in (24). When the metal is thoroughly melted, the ſcoriæ are ſcummed off with a ladle: if braſs form any part of the compoſition, the proper portion is put into the furnace and ſtirred with the ladle, the better to mix it with the copper. When theſe ſubſtances have attained a proper degree of fuſion, the tin is thrown in and the fire increaſed for half an hour and more, till the whole has acquired the degree of heat and liquidity judged neceſſary; the ſcoriæ then ſwim on the ſurface, and are in part diſſipated with a luminous appearance; the remainder is ſcummed off. The mixture is then well ſtirred and the furnace opened to let it run into the moulds.

If no braſs be uſed, the proper quantity of tin is put into the furnace after the ſcoriæ have been drawn away; and when the mixture is ſufficiently liquid, it is ſtirred and the furnace opened.

109. In recaſting old guns, mortars, &c. the tenacity and hardneſs of each piece before it is put into the furnace ſhould be aſcertained, in order to find what quantity of copper or tin ſhould be added to make it of a particular quality: ſome of the new compoſition ſhould be fuſed and proved to know whether it is of a proper tenacity and hardneſs. If it be found that the old metal is unfit for the purpoſe, it ſhould be abſolutely rejected; or only uſed in caſting ſtone mortars. Being thus aſſured of the goodneſs of the new compoſition, let the furnace be heated; as the metal muſt neceſſarily remain for a longer time in fuſion, ſuch a calcination may take place as to deſtroy the proportion between the tin and copper (24); on which account a quantity of tin ſhould be added to make up for what may have been loſt: this has always been deemed neceſſary, and the proportion is fixed at 1 or 2 in the 100, according to the time that the bronze firſt put into the furnace remains in fuſion. But experience and careful obſervation of the fuſion of metals will beſt enable the founder to decide what quantity of tin ſhould be added: A bright flame denotes that the tin is in abundance; a red

flame that it is in ſmall quantity, and a green flame that it is almoſt diſſipated. Before the furnace is opened the compoſition ſhould be ſtirred; and if there be the leaſt reaſon to be dubious of its quality, a little ſhould be taken out with an iron ladle, and when cold be carefully proved. If the recaſt metal contained any braſs, the zinc will be totally diſſipated (23); therefore when braſs ſhould form any part of the new compoſition, a proportion muſt be added before the furnace is opened, not exceeding (28) half the quantity of tin.

110. The furnace is heated before the copper is put in (108) to give it the neceſſary degree of heat which it would not otherwiſe attain; for if it were put in before, the part of the hearth covered by the copper and the copper itſelf would never be properly hot; therefore not to leſſen the degree of heat in the furnace or in the metal already fuſed, ſmall quantities are put in at a time, that the liquid matter may ſpread equally over the whole ſurface. The braſs and tin are put in when the copper is thoroughly fuſed, and juſt before the furnace is opened, to avoid as much as poſſible the ſublimation of the zinc, and the calcination of the tin (22, 23, 24); they are then well ſtirred, ſince the motion produced by the fire is not ſufficient to mix them thoroughly.

When old ordnance containing very little tin is to be recaſt, the founders generally put two or three large guns into the furnace, in ſuch a poſition that they may cover as little as poſſible of the baſe, and a moderate fire is kept up for five hours that the furnace may be well heated before the metal begins to fuſe. If on the contrary, the metal to be recaſt contain much tin, as bell-metal; the founders knowing that the tin accelerates the fuſion (24) put a great quantity into the furnace before the fire is lighted, taking care ſo to arrange the pieces that the flame may penetrate between them before they melt; and the heat is kept moderate till the fuſion begins; this in the language of the founders is called *putting them into a bath.*

111. The calcination of copper and tin may be partly repaired by the introduction of phlogiſtic ſubſtances, but it is not judged expedient to have recourſe to this method in large furnaces: the founders contenting themſelves with dropping, while the melted matter is running into the moulds, ſome unctuous ſubſtances, as fat, ſuet, &c. to prevent the calcination.

112. The

112. The furnace ſhould not be opened (108) till the metal has acquired a proper degree of heat: for if it be too hot when run into the mouids or not hot enough to take the form, the guns will in either caſe be defective. Tin being a ſolvent to copper, it would ſeem that theſe two metals ſhould form a perfect mixture when in fuſion without afterwards ſeparating; as is the caſe in the ſmall proceſſes of the chemiſts and metallurgiſts: but experience ſhews that the effects are different in the more extenſive operations of the foundry: ſince in guns the metal is commonly harder at the breech than at the chaſe or muzzle, for theſe parts being nearer to the top of the mould contain leſs tin than the breech does. If from metal of the ſame quality and liquidity ſmall and large guns be caſt; in the former there will be very little difference between the tenacity and hardneſs at the breech and the other parts; but in the latter it will be very ſenſible from the longer ſpace of time that the melted metal takes to congeal in a large mould than in a ſmall one. Whenever the founders neglect to make a perfect and equal connection between the different metals, there are always particles of tin found unmixed with the copper, particularly in large guns; ſome are ſeen almoſt pure on the outſide of the guns in a long ſerpentine ridge, others forming ſmall lumps in the copper: the ſame circumſtance occurs in vents that have run, ſome being irregularly enlarged; while in others caſt at the ſame time, there is no apparent defect. Theſe irregularities proceed in ſome guns from cavities contiguous to the vents; while in other guns no ſuch cavities are viſible.

Among the different guns that were examined, there was a 4 pr. that had been practiſed with, at ALEXANDRIA; in 60 rounds fired from this piece, the vent was enlarged to three times the original ſize, and a cavity formed ſpreading from the vent in a ſerpentine direction towards the muzzle of about 2 inches in length, $\frac{1}{4}$ in its greateſt and $\frac{1}{5}$ in the leaſt breadth: the vent being enlarged by the chiſſel to introduce a bouch, a ſtratum of tin was obſerved beginning at the exterior ſurface of the piece, and deſcending vertically to the top of the cylinder; the chiſſel penetrated the tin more eaſily than the copper that ſurrounded it. This ſeparation is attributed to the property which the copper has of ſetting before the tin; whence the latter remaining fluid for a longer ſpace of time inſinuates itſelf by its weight between the in-

interſtices of the copper, already in part congealed, deſcends towards the bottom, and lodges in any cavity it finds.

113. This circumſtance did not eſcape the obſervation of our anceſtors, and various expedients were devised in the laſt century for remedying it; ſome threw a quantity of tin into the trough that conducted the melted matter from the furnace to the mould, when they judged that the mould was about $\frac{2}{3}$ full; others thought to prevent it by the uſe of braſs. Some are ſaid in order ſuddenly to congeal the metal, to have drawn out the iron cores from the moulds while hot, and to have thrown water into the vacant ſpace; others again were anxious to form very long and weighty heads, that the copper being ſtrongly compreſſed while ſetting, the tin might not be able to deſcend. Experience has proved that this laſt expedient is the beſt; ſince in pieces of large calibre, the difference between the hardneſs of metal at the breech and muzzle is not very conſiderable, and hardly ſenſible in pieces of ſmall calibre.

114. Gun-metal is fuſible, not only by a great heat, but even by a moderate one, with the aſſiſtance of ſolvents. It has been already obſerved that tin is a ſolvent of copper, of which it accelerates the fuſion; but as the quantity of tin cannot be increaſed without altering the quality of the bronze, this expedient can only be uſed ſo far as the proportion of the ingredients will permit. Tartar and nitre are the moſt powerful ſolvents; when mixed together in equal quantities, the chemiſts term the compound a *white flux*; when the quantity of tartar is double that of the nitre, a *black flux*. As theſe two fluxes, eſpecially the former, are very active, much care and circumſpection muſt be obſerved in uſing them, to avoid the damage that the furnace would be expoſed to, from the violent agitation they occaſion. When gun-metal is made extremely hot, it is often very ſpungy and porous, particularly towards the muzzle, ſo that when filled with water, it exudes and oozes through. Tartar is uſed when from the great rarefaction of the air ariſing from extraordinary heat, the fire is rendered inactive, and the metal is infuſible *per ſe*. But if fire alone will anſwer, the founders ſtir and mix the ſubſtances well together before they open the furnace, the melted matter then runs into the moulds; and this method has been found ſufficient to render it homogeneous; for, if ſmall quantities be taken out of the furnace with an iron ladle, while

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the metal is running into the moulds, at the beginning, the middle, and end of the proceſs, the ſeveral pieces, when cold, will be homogeneous.

115. If an exceſſive heat, whether produced by fire or a combination of ſolvents, be attended with bad effects; a deficiency in that reſpect is not leſs pernicious: for independent of the imperfect mixture, the metal does not ſet properly in the moulds; whence proceed the cavities and flaws frequently obſervable on the outſides of guns after proof: theſe can neither be attributed to the intrinſic quality of the bronze, nor the want of proportionable thickneſs, but to the defect of heat and mixture; ſince the external flaws do not extend and communicate with the bore: from the ſame cauſe proceed the aſperities viſible on the ornaments and bas-reliefs.

The deficiency, in point of heat, does not always ariſe from too ſmall a quantity of wood being uſed to heat the furnace, ſince with the ſame quantity it takes ſometimes 36 or even 48 hours, to effect what at other times 16 or 18 are ſufficient to do. This can only be accounted for from a want of elaſticity in the atmoſphere, which prevents the wood from burning with proper activity; or from the neglect of the workmen in removing the cinders, which partly ſtops the reverberation of the flame; thus the fire not being ſo intenſe, it is longer before the metal acquires the proper degree of fuſion.

116. There are ſome accidents which baffle the utmoſt caution, as they proceed from variations in the ſtate of the atmoſphere. If the melted matter while running into the mould be expoſed to a cold wind, it may be ſuddenly congealed, which will prevent a due tenacity in the particles when ſolid. After the mould has been heated, if the atmoſphere become ſuddenly loaded with vapour, the mould will imbibe humidity; and the melted metal will extract the moiſture, which ruſhing out and bubbling vehemently, will diſturb its ſetting. On the contrary, when the mould is perfectly dry, repeated experience proves that the metal on running into a hot recipient, ſets better, and becomes more tenacious and denſe, but leſs hard than when the recipient is cold.

117. Since cavities proceed from the ſpunginеſs of the copper, or from the coldneſs and moiſture of the atmoſphere or mould; they are found in all parts of the gun indiſcriminately,

minately, and can neither be avoided or diſcovered before the proof, particularly if the quantity of tin be ſmall: but if it be large, as in bell-metal, theſe cavities are ſeldom ſeen, unleſs the metal be run into the moulds before it is ſufficiently liquid. If the proportion of tin in gun-metal be 16 in the 100, the heads very long and thick, and the furnace not opened till the metal is properly fuſed and mixed, there will ſeldom be any cavities large enough to affect the ſervice of the piece.

As no rule has yet been laid down for aſcertaining the abſolute degree of heat, founders muſt depend on their own obſervation; and though they may ſometimes be deceived (107) yet a competent ſhare of knowledge derived from experience will enable them to judge with tolerable accuracy when the furnaces are properly heated.

118. From the preceding obſervations on gun-metal and the method of caſting artillery, we may conclude:

1. That the metal muſt have certain phyſical qualities to enable the guns to reſiſt the forces that tend to deſtroy them.

2. That great art is requiſite in reducing the metals to a proper degree of liquefaction.

It reſts with the officers of artillery appointed to fix the proper proportion for the different natures of guns that are to be caſt, to aſcertain the phyſical properties of the gun-metal; it depends on the founders to flux the metals, and form the moulds in ſo nice and accurate a manner, that the principles laid down by the artillery officers may be punctually adhered to. From a want of attention to theſe diſtinctions, it has frequently happened that every thing being left to the *mechanics*, they, either through ignorance of the abſolute neceſſity of having particular properties in the metal or of the means of procuring them, formed the mixture without the leaſt judgment; whence ariſes the great difference ſometimes found in guns caſt by the ſame founders after the ſame model.

CHAP.

## CHAP. VIII.

### Of the Vents of Guns.

119. THE poſition of the vent contributes alſo to modify the inflammation and exploſion of the charge. (Pl. 3, Fig 8) If in the gun ABM the vent QP correſpond to half AN of the charge, it will be the moſt advantageous poſition for obtaining the greateſt force from the given quantity of powder; but then the motion of the breech, though of the proper weight (84) will be ſo violent, as to render the firing totally irregular, and of courſe the fire-arm uſeleſs. The vent ſhould be placed at AC correſponding to the bottom of the bore, which will obviate the ill conſequnces attending the former poſition; and if the bottom of the bore inſtead of being hemi-ſpherical be plane, the charge will be brought nearer to the vent, more powder will take fire, and the exploſion be more violent, without cauſing ſuch an irregular motion in the breech.

120. Chambers in guns are liable to great inconveniences from the alteration of their figure, as happened at the experiments with the *Sarcophagus* (36). This gun had at the bottom of the bore a ſmall cylindric chamber ABCD (Pl. 3, Fig. 9) of which the diameter AC was $1\frac{4}{10}$ inch and the length AB 2 inches, the communication F to the vent FG was diſtant from A $1\frac{4}{10}$: the part FN of the vent made in the gun itſelf was in length $3\frac{7}{10}$, the remainder GN was filled with an iron ſcrew HLMK $2\frac{2}{10}$ in length, which had been well worked and tempered. After 500 rounds the metal was much corroded at F, and round the orifice AC of the chamber; and the upper part PABF was conſiderably damaged towards N. This increaſed very much in the next 300 rounds; the clefts extending towards N were $1\frac{1}{4}$ inch in length; the pricked line QQQ ſhews the alteration that took place in the figure of the chamber. The part NG of the vent formed by the iron ſcrew was regularly enlarged to nearly twice the original diameter: but by the aſſiſtance of this bouch the piece might yet have been frequently fired, without apprehending any great increaſe in the ſize of the vent;

vent; its position was not at all altered. This single experiment shews the necessity of suppressing the use of small chambers in guns.

121. Several observations and experiments might be adduced to prove that when the bottom of the vent corresponds with the upper part of the bore, it is a long time before it changes its form; and that if the metal be corroded, it is only round the lower orifice.

122. It has been observed (4) that the vents of guns run sooner as the proportion of tin is the greater; and in the second chapter the necessity of having a hard metal to prevent cavities being formed in the bore was insisted on; but this condition can only be obtained by increasing the quantity of tin, and thereby rendering the vent liable to run after a very little firing; and it is well known that when the vent is much enlarged, there must be great irregularity and a considerable diminution of force in the discharge: it is necessary therefore to form the vent of some more resisting metal, which when enlarged may be easily taken out and replaced; the best expedient hitherto devised, is to insert into every gun previous to its being carried on service, a screw bouch which may be replaced at pleasure.

123. From satisfactory experiments made on the resistance of simple and compound metals with a view to determine which is the best for bouching guns, it is in general found that their resistance is in proportion to the difficulty of fusing them in the crucible. The following metals were proved with the machine described in the Treatise on Powder (139) and found to decrease in resistance from the first to the last.

1. Forged iron well worked and welded with the hammer.
2. Iron of the second smelting.
3. Pure copper.
4. German brass.
5. Gun-metal containing $\frac{1}{9}$ of tin.
6. Assayed gold.
7. Assayed silver.
8. Lead.
9. Tin.

Of these metals the three first are least corroded by the action of powder; but forged iron is the only one that can be depended on for making screw bouches (122). Gun-metal

metal containing tin in the ratio of 16 to 17 in the 100 corrodes more eaſily than aſſayed gold; but at 4 to 5 in the 100 it reſiſts more than German braſs; for which reaſon, as was before remarked, ſoft gun-metal was for a long time in great credit. But theſe reſiſtances are merely relative and can only apply to determined circumſtances; for if the quality or quantity of the powder be altered, the wads rammed with more force, or the piece much heated by frequent firing, the metal will be the ſooner corroded and the vent enlarged.

124. The firſt method adopted for repairing the vents of guns that had run, was the application of a bouch: afterward in hopes of totally preventing or at leaſt deferring this accident, they put into the mould a piece of copper or iron at the place where the vent would be: this expedient was ſoon abandoned, on finding that the liquid metal on coming in contact with a cold body, bubbled and formed cavities contiguous to the vent: and one of the four following methods was univerſally adopted.

The firſt conſiſted in enlarging the vent A B C D (Pl. 3, Fig. 10) when damaged towards the middle F G and filling up the cavity with gun-metal; the metal when cold was perforated to form a new vent.

The ſecond method differed from the firſt, only in filling the cavity with pure copper.

In the third method, the vent A B C D (Pl. 4, Fig. 11) was enlarged as before, and an iron bouch P applied with the projection Q Q; melted metal was then poured into L M which when cold held the bouch P very firmly; afterward a new vent H K was drilled.

(Pl. 4, Fig 12) The fourth method was to enlarge the vent very conſiderably in form of a truncated cone A M K E, the ſides of which Q R D B L E ſerved as a female ſcrew to receive an iron bouch; in the axis of which was drilled a new vent F G. Theſe different methods of repairing the vents of guns may be applied according to the damage that the piece has ſuſtained, but are not equally good. In the firſt method the vent may run a ſecond time, if there be too much tin in the metal. By the ſecond, the vent is leſs liable to corrode; but the copper from its great ductility may ſpread and lengthen, and being detached from the ſides of the cavity, the whole bouch may be blown into the air. The third method is preferable to the two former, ſince the bouch gives more reſiſtance, and is leſs liable to the above accidents.

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In the fourth, it requires more labour to prepare the cavity; but a freſh ſcrew may be inſerted when the firſt is corroded. The old method of uſing ſcrew bouches was very imperfect; ſince they were obliged to vary the diameter in each gun in proportion to the degree of corroſion.

125. In order to derive every poſſible advantage from ſcrew bouches, and render their uſe more ſimple, expeditious, and general, the following precautions ſhould be obſerved.

1. To apply during the time of peace to all guns, particularly to battering cannon, a ſcrew bouch of iron in one of the two methods expreſſed in figure 12 and 13; they ſhould be formed on the ſame model for all pieces of the ſame calibre, that there may be always a quantity in ſtore.

2. The head of each bouch ſhould be ſo formed that it may be eaſily ſcrewed and unſcrewed; and of ſuch a length, that the bottom may exactly correſpond with the upper part of the cylinder.

3. Not to diminiſh the metal at the breech too much, the diameter of the bouch ſhould be leſs than $\frac{DQ}{2}$; and to prevent the neceſſity of frequently replacing it, its diameter ſhould not be leſs than $\frac{DQ}{4}$.

4. The vent ſhould (119) correſpond with the bottom of the bore, which ſhould be a plane figure. If theſe operations be executed with exactneſs and preciſion by ſkilful workmen, the reſiſtance will be fully ſufficient; and there will be no danger of the flames paſſing among the ſpirals to damage and corrode them.

126. The reſiſtance of the ſcrew bouch may be eaſily aſcertained: (Pl. 4, Fig. 12) ſince before it can yield to the action of the powder, it muſt be driven forcibly out of the female ſcrew and be ſeparated from its ſpirals; or it muſt break off and carry away with it the ſpirals of the other ſcrew, which would leave a vacuum N B D Q; or it muſt break the ſpirals of both. Now as the tenacity of iron far exceeds that of gun-metal, the ſpirals of the female ſcrew muſt firſt yield to thoſe of the bouch; and if the circumference of a ſpiral anſwering to the diameter B D be called = C and its length D Q = $m$, $c\,m$ will be the ſection of the fracture; this

ſection

ſection multiplied into $q$ = the tenacity of the metal will give $cmq$ for the reſiſtance of the female ſcrew. The formula 9962 $ns$, expreſſes the preſſure of the elaſtic fluid againſt a ſuperficies = S. Then if half the diameter B D = $r$, and its circumference = C, $S = \frac{rc}{2}$ will be the ſuperficies of the circle, againſt which the elaſtic fluid acts in the direction F G; then 9962 $nx\frac{rc}{2}$, will expreſs the force with which the powder acts againſt the baſe of the bouch. For example, if under circumſtances the leaſt favourable to the reſiſtance of the bouch, $r = \frac{m}{4}$, $n = 1200$ (33) and the metal of a leſs tenacious quality be heated as much as it can be on ſervice, $mq = 7358758$ (35) the reſiſtance of the bouch. Now ſuppoſing $m = 1$; then $4981nr = 4981 \times 1,200 \times \frac{1}{4} = 1444300$ for the action of the powder againſt the baſe of the bouch: thus the reſiſtance of the female ſcrew will be more than five times the force that tends to drive the bouch from its place; an equilibrium between the propelling and reſiſting powers will be then fully eſtabliſhed, if only part of the bouch Q R = $\frac{1}{5}$ of D Q be ſpirated.

127. When the baſe of the bouch correſponds with the upper part of the bore, the action of the powder againſt it is as the preſſure: but when the bouch only reaches to L R, and leaves the vacuum D L R B, then the elaſtic fluid acts againſt it with ſo much the greater force, as L R is diſtant from the upper part of the bore; and greatly exceeds the preſſure that it would exert againſt the baſe, were the bouch in the former ſituation. The reflections in the 2nd chapter on the orbicular cavities formed in the bores of guns caſt of ſoft metal, by the impulſion of the elaſtic fluid, will convey a juſt idea of this force.

128. To ſhorten the operation of making the ſcrews, and at the ſame time to obtain a reſiſtance ſuperior to the force of the powder, the bouch may be made in the following or any ſimilar manner. (Pl. 4, Fig. 13) Let it be ſpirated only from P to L; let P L be about $\frac{1}{4}$ of F G and the remainder L F be in a form of a troncated cone H K N H, the diameter H H being leſs than B D, to form a ledge B H H D, upon which may be placed a thin circular plate of ductile

ductile metal, as pure copper; ſo that when P L is ſtrongly ſcrewed down, the plate may ſpread and fill up the ſpace between P L and H F ſo exactly, that none of the elaſtic fluid may be able to penetrate among the ſpirals. The formula (126) will ſerve to compare the reſiſtance with the force of the powder, that acts againſt the baſe K N of the bouch: 4981 $nrc$ expreſſes the force of the powder, $cmq$ the reſiſtance of the bouch; put $\frac{KN}{2}$ in the place of $r$ and the circumference correſponding to the diameter K N in the place of $c$. If the circumference $= c$ correſpond to the diameter B D of the ſpirals, then in the ſecond formula put the length L P in the room of $m$; and ſince circumferences are proportional to their diameters, theſe may be ſubſtituted and the formulas will be $2460\ n \times \overline{KN}^2$, $BD \times LP \times Q$.

129. The reſiſtance of bouches made on this principle have been found more than ſufficient in practice. The experiments made in 1771 prove the goodneſs of the bouches; (Fig. 9 and 13) their reſiſtance is amply ſufficient, and when damaged they may be eaſily taken out and replaced (127). The bouch (120) was neither moved or corroded in the 800 rounds fired from the *Sarcophagus*; and the ſame was the reſult of the experiment (34) with a bouch (Fig. 13). When the bouches were taken out, neither the male nor female ſcrews were in the leaſt altered, nor had the elaſtic fluid or the water which remained in the gun for 5 hours paſſed the ledge B D. In the gun called the *Paphos*, which in 1771 was fired in the ſame manner as the *Invincible* (34) with a bouch (Fig. 13), the ſame effects were obſerved. The operation of taking out and replacing the bouches takes up but a few minutes; it may be performed upon the batteries without diſmounting the guns.

CHAP.

## CHAP. IX.

### Of the Examination and Proof of new Guns.

130. It was obſerved in the 7th chapter, that ſucceſs in caſting guns does not entirely depend on the ſkill and ability of the founders, ſince it is greatly ſubject to caſualties. The King's ſervice requiring that, beſide the precautions taken at the time of caſting, the greateſt attention be afterwards paid to detect any negligence or error; every gun before it is uſed ſhould be ſcrupulouſly examined and ſubjected to various proofs, in order to be certain that the founder has adhered to the inſtructions he received.—The object of theſe examinations and proofs is to aſcertain:

1. Whether the guns are conſtructed on the proportions given to the founder.

2. Whether before the metal was run into the moulds, the neceſſary precautions had been taken to avoid all ſeparations between the metallic particles capable of producing an unequal reſiſtance.

3. Whether the tenacity of the metal is proportional to the thickneſſes of the piece; and its hardneſs ſufficient to prevent orbicular cavities from being formed on firing very large charges.

131. To know whether a gun be properly conſtructed, two inſtruments are uſed: the firſt ſerves to ſhew whether the piece has been truly bored, and the thickneſſes of metal properly diſtributed; by means of the ſecond, the exact figure of the bore is traced upon the firſt, whereby the leaſt flaw or deviation from the cylindrical figure is diſcovered and aſcertained. A mirror is afterwards uſed to diſcover by the reflection of the ſolar rays, what cavities, inequalities or other defects there may be; and with the little iron inſtrument called the *ſearcher*, their depths and diameters are meaſured.

132. To know whether there be in any part ſuch a ſeparation of the metallic particles, as to penetrate from the exterior ſurface to the interior cylinder, the gun is filled with water and placed with the breech downwards to increaſe its force

force and make it more eaſily paſs between any interſtices of the metal; it is further preſſed with a high ſponge; and in this ſituation the gun is left for three or four hours. This proof ſhould never be made when the water can freeze.

133. If during theſe examinations (131, 132) any defects ſufficient to make the ſhot ſtrike againſt the ſides of the gun, or any holes in the charging cylinder or bore be diſcovered; if the axis be not exactly in the center, the trunnions properly placed or any opening or cavities through which water oozes; in a word, if the piece have any defects that can render it unſerviceable or dangerous, or that can tend to prevent the ſhot from being thrown in a true direction, and no ſafe remedy can be applied; the gun ſhould be without heſitation rejected.

134. When no ſuch defects are diſcovered, the other proofs for aſcertaining with the greater certainty the nature of the caſting and the qualities of the metal may be proceeded to. To this end, a few rounds ſhould be fired in ſuch a manner, that any defects may be diſcovered as fully as they would be, after a long continued firing with the ordinary charges of powder.

135. To determine the proper quantity of powder for proving guns, it is neceſſary to advert to the circumſtances that modify its force, from the beginning of the inflammation at the bottom of the bore, till the ignited fluid reaches the mouth of the piece; theſe modifications have been enlarged on in the Treatiſe on Powder, and may ſummarily be reduced to the following:

1. The preſſure of the elaſtic fluid in the charging cylinder does not depend on the quantity of powder, provided that it be equally well collected; but on the reſiſtance oppoſed to its exploſion towards the mouth of the piece: and the other ordinates of the ſcale of preſſures increaſe in proportion to the greater quantity of powder that is fired in the piece.

2. On comparing two equal charges of powder of different qualities to which an equal reſiſtance of ſhot and wads is oppoſed, the preſſures, excepting the firſt by which the ſhot is put in motion, are greater in proportion as the powder is ſtronger: the difference between the correſponding ordinates proceeds from the greater quantity of fluid produced in equal times, in two powders of different qualities; whence it reſults, that

that the elaſticity of the fluid in the charging cylinder is greater in the ſtrongeſt powder, though the preſſure by which the ſhot is firſt put in motion be equal in both charges.

3. The reſiſtance to the exploſion of the powder toward the mouth of the piece, is compounded of the weight and friction of the ſhot and wads: the reſiſtance from friction ceaſes as ſoon as the ſhot and wads are in motion; but the reſiſtance from the weight of the ſhot exiſts during the whole length of the piece, and is greater as the elevation at which the gun is laid is higher; this reſiſtance may be calculated in the ratio of the right ſines of the angles of elevation.

4. The fluid generated at the bottom of the bore on ſtriking the ſhot is reflected laterally againſt the ſides of the gun with ſo much the more force, as the charge occupies a greater ſpace, or as all the powder is more inſtantaneouſly inflamed: whence proceed orbicular cavities, whenever the hardneſs of metal is not ſufficient to reſiſt the impulſion.

136. From the preceding remarks we may infer that;

1. The proof charge ſhould never occupy leſs ſpace in the bore than the largeſt ſervice charge.

2. The gun ſhould be laid at a higher elevation than when mounted on its carriage.

3. The powder ſhould be ſtronger than what is generally uſed, its quantity combined with the greateſt reſiſtance of the ſhot and wads, and proportioned to the largeſt ſervice charge, in the ratio of the metal when cold, to the metal heated ſo as to fire powder (35).

4. If a ſhot made of a ſoft metal as lead, tin, &c. by any irregular movement proceeding from the ſtrength of the charge ſtrike againſt the ſides of the gun, it ſhould be unable to make the leaſt impreſſion.

137. The defects of a gun loaded in this manner will be as fully diſcovered in a few rounds as with a great number fired in the common mode; nor will there be the leaſt reaſon to be apprehenſive of burſting the gun, if it has been caſt in the manner, and with the proportions already preſcribed. When the guns have been thus fired, they ſhould be again ſubjected to the water proof and re-examined: and if any flaw that may prove detrimental to the ſervice can be diſcovered (133) they ought to be rejected.

138. There may be ſome defects ſo ſlight as not to merit attention; while there are others that muſt be prejudicial, according to their nature and extent; as the eccentricity of the bore, the number, depth and ſituation of the flaws or cavities, the wrong poſition of the vent, or a failure in other points previouſly concerted with the contractor. As, on the one hand, nothing ſhould induce officers to receive guns that cannot be depended on; ſo, on the other, they ſhould not be over ſcrupulous in their examination, leſt the founders under pretence of the minute ſtrictneſs of the ſcrutiny enhance their price.

139. Iron guns ſhould be ſubjected to the ſame proof and examination: but as the hardneſs of the metal is aſcertained, there will be no reaſon to apprehend any orbicular cavities being formed in the charging cylinder, or any impreſſions made by the ſhot in the bore. If properly caſt of metal of a good quality, they may be proved with iron ſhot without fear of damaging or hurting them; the quantity of powder ſhould be determined by the thickneſs of metal, agreeably to the rules laid down in the 6th chapter.

140. The ſame precautions and care ſhould be taken in proving and examining mortars: but any little hollows or flaws in the chaſe may be diſregarded, unleſs from their number and proximity, there be reaſon to apprehend an eſſential defect in the interior of the metal.

# SECOND PART.

## OF PROJECTILES.

141. THERE are two general methods of annoying an enemy: with miſſile weapons; or with pointed and cutting inſtruments. Under the firſt head, the ancients made uſe of the *baliſta* and *catapulta*, for throwing large ſtones and arrows to great diſtances; and of *ſlings* and *bows* for throwing them to ſhorter diſtances.

The

The invention of the powder gave riſe to the caſting of guns and mortars; which project iron ſhot and ſhells of different ſizes to very great diſtances, for the deſtruction of men, and the demolition of fortifications and buildings. The non-commiſſioned officers and ſoldiers of artillery perform the operations requiſite for producing theſe effects. The theoretical part of the profeſſion conſiſts in certain principles and rules, with which the officers ought to be fully acquainted: as from mere practical knowledge they can never hope to be diſtinguiſhed; nor can their country reap from their exertions the advantages expected from a corps, purpoſely ſet apart in all armies for this particular ſervice.

Our anceſtors feeling the neceſſity of regulating their practice by fixed principles, were ſoon convinced, that, to expertneſs and adroitneſs in the mechanical parts, it behoved them to join a juſt theory; that from a knowledge of cauſes they might be enabled to account for effects, and conduct their experiments without the confuſion and abſurdity inevitably attendant on an erroneous ſyſtem.

If it hath not already been ſufficiently proved, that an artilleriſt ſhould be converſant in phyſics and mechanics; the ſecond part of this work will clearly demonſtrate, that unaſſiſted by ſcience, he never can enſure facility and œconomy in execution, which is the moſt certain and ready method of obtaining victory, the ſole object of military operations.

142. To this end, *each ſhot ſhould ſtrike the object in the manner that will produce the beſt effect that circumſtances admit of*; or in other words, *the projectile ſhould produce the greateſt effect poſſible in any particular caſe.* The officer then, who commands a battery, ſhould examine the calibre, ſhape and dimenſions of the artillery; the qualities and proportions of the powder: the cauſes that may modify in any conſiderable degree the initial velocity of the projectile; the reſiſtance of the air to its movement; it's nature and form: the quality and ſize of the objects againſt which the fire is to be directed; their relative and abſolute ſituation: the poſition of the enemy's troops; and the nature of the ground. Each of theſe circumſtances merit a particular diſcuſſion.

## CHAP. I.

### Of the Initial Velocity of Projectiles.

143. THE initial velocity of ſhot and ſhells muſt be indiſpenſably known, before the problems in projectiles can be ſolved: but as it may be much diverſified by the quantity and quality of the powder, the force uſed in ramming the wads, the elevation of the guns, and the length of the bore; it is neceſſary to treat all theſe circumſtances more in detail: the powder will be ſuppoſed to be the fine war-powder in a good ſtate of preſervation.

1. The largeſt ſervice charges for heavy guns, are equal to $\frac{1}{2}$ of the weight of the ſhot in 32 and 16 prs. and to $\frac{3}{4}$ in 8 and 4 prs. Theſe charges are only uſed on particular occaſions; the wads are well rammed, that the powder being cloſely collected at the bottom of the bore, may all take fire in the piece; and that the inflammation of each grain being as inſtantaneous as poſſible, the ſhot may have the greateſt initial velocity.

2. The medium charges are $\frac{3}{8}$ of the weight of the ſhot in 32 and 16 prs. and $\frac{1}{2}$ of its weight in 8 and 4 prs. Theſe charges are commonly uſed in ſieges, for demoliſhing works, diſmounting the enemies artillery, or enfilading troops; two gunners give five ſtrokes of the rammer to the wad over the powder, and three to that over the ſhot.

3. The ſmaller charges are equal to $\frac{3}{4}$; and the leaſt to $\frac{1}{2}$ of the medium charge. Theſe are only uſed in particular caſes, which will be hereafter pointed out; and are always ſuppoſed to be wadded in the ſame manner as the medium charges, in order to compare the initial velocities of ſhot, impelled by different quantities of powder.

4. As the difference in the diameter and weight of ſhot cauſes a great difference in the initial velocity, the ſhot are ſuppoſed to be of the diameter and weight, and the guns of the calibre preſcribed by the king's order, and caſt agreeably to the proportions laid down in the firſt part of this work. Shot made, as directed in the

firſt

firſt book of artillery, have been found adequate to every purpoſe; nor can their ſurface be more poliſhed, or their figures more perfect, without incurring an exorbitant and unneceſſary expence.

144. The initial velocities of ſhot are determined from experiments made with ſkill and diſcernment, and conducted with care and circumſpection: before we proceed to the method of determining them, it will be neceſſary to mention the principles adhered to in carrying on the experiments.

1. The piece was always loaded in the ſame manner, and placed exactly in the ſame poſition, leſt the reſult might be erroneous.

2. Since effects are always proportioned to their cauſes, when any remarkable difference ariſes in the courſe of the experiment, it ſhould excite no amazement; as it muſt proceed from negligence or accident. Some practitioners take the mean reſult of all experiments, but concluſions drawn from thence muſt be faulty.

3. In ſpite of the utmoſt precaution, there will be ſometimes a ſlight difference, proceeding from the manner of placing or wadding the powder, &c.

If the variations be not very great, a few more rounds may be fired; but the mean reſult only of thoſe taken that approach neareſt to each other: this may then be conſidered as the abſolute reſult. If, for example, the queſtion be concerning the length of ranges; the mean only of thoſe ſhould be taken, whoſe differences do not exceed 2 in the 100, and no regard paid to the others. But, ſhould the ranges vary conſiderably, it will then be neceſſary to examine carefully every part of the proceſs, to diſcover the cauſe of the variations, and be enabled to make freſh experiments in a more exact manner.

145. There are three methods of determining the initial velocity of ſhot:

1. By meaſuring their penetrations into a homogeneous butt of a known conſiſtency.

2. By analyſing and reſolving into its ſimple movements, the curve deſcribed by the projectile on quitting the piece.

3. By deducing it from the thickneſs of metal of the fire-arm, when it is in equilibrio with the preſſures of the elaſtic fluid, in every point of its length. The

third method is applicable to fuſils and pieces of very ſmall calibre; but not to guns of large calibre, fired with the common charges of powder: becauſe in the latter, the initial velocities are compounded of the impulſion and preſſure, as has been explained in the *firſt* part.

146. The initial velocities are found very nearly by the firſt method (145, No. 1.) if the butt be perfectly homogeneous and conſiſtent. To determine its conſiſtence, fire a piece of ſmall calibre, with an iron ſhot 1 inch in diameter $= D$: and meaſure the initial velocity $= u = 1200$ feet, (Treatiſe on Powder 164, 165). Then the piece being loaded and fired as before, the penetration of this ſhot into the butt will be 15 inches $= S$; and ſubſtituting theſe data in the formula $fS = DU^2$; we ſhall have $f \times \frac{5}{4} = \frac{1}{144} \times 1200^2$; then $f = 96000$ for the conſiſtence of the butt: let it be written in the formula, which then becomes $96000\,S = DU^2$. Place the gun, the velocity of whoſe ſhot is ſought, very near the butt, and fire ſome rounds in a horizontal direction, in order to obtain the mean $= S$ of the penetrations of the ſhot; ſuppoſe it $= 8$ feet, and the diameter $D$ of the ſhot $= 4$ inches; then by ſubſtituting theſe data in the formula, $96000 \times 8 = \frac{4}{144} U^2$; hence $U = \sqrt{\frac{96000 \times 8 \times 12}{4}} =$ 1517 feet, the initial velocity ſought. In theſe experiments, the penetrations ſhould be at ſuch a diſtance from each other, that the looſening of the earth by the firſt ſhot, may not facilitate the entrance of the others; the leaſt difference will be then perceptible, ſince the penetrations of the ſame ſhot are as the ſquares of the initial velocities.

147. To determine the initial velocities, by analyſing the curve (145, No. 2); let us take the firſt part of the curve, where the effect of gravity has not been ſenſibly altered by the reſiſtance of the air. It is a matter of indifference, whether the ſpace that the ſhot paſs through by the gravitating or impelling power, be firſt conſidered; ſince the latter may be deduced with equal facility from the former, as the former from the latter. Let us in the firſt place examine the ſpace paſſed through by the power of gravity.

(Pl. 5, Fig. 14.) Let the gun A B, mounted on its carriage, be placed on an even and ſolid platform, and laid in a horizontal direction A C; ſo that the ſhot at the firſt graze may

may touch the earth in the point G of the horizontal line D F: the vertical diſtance K G between the two planes, expreſſes the ſpace = S paſſed through by the gravitating power, and the horizontal line D G = A K expreſſes the length of the range, or the ſpace = $q$ paſſed through in the ſame time by the impelling power. If the known value K G be ſubſtituted in the formula $S = \frac{32.18\,t^2}{2}$, it will give with great preciſion the time $t = \sqrt{\frac{2\,K\,G}{32.18}}$, in which the ſhot is driven from A to K by the impelling power. Having fired ſeveral rounds, and meaſured the length D G of the ranges, take the mean = $q$ (144, No. 3); and conſidering this ſpace as uniformly paſſed through, eſtabliſh the following proportion; the time = $t$, is to the ſpace paſſed through = $q$, as one ſecond, is to the ſpace = $\frac{q}{t}$; which the ſhot would move through in one ſecond, if there were no reſiſtance from the air; this ſpace is termed the initial velocity. For example, K G = 4 feet, then $t = \sqrt{\frac{2\times 4}{32.18}} = \frac{1}{2}$ ſecond; and ſuppoſe A K = 700 feet, then $\frac{q}{t} = \frac{q}{\sqrt{\frac{2KG}{32.18}}} = \frac{700}{\frac{1}{2}} = 1400$ feet, the initial velocity ſought. The initial velocity thus found, is not abſolutely juſt, ſince the ſhot, from the moment of quitting the piece till it touch the ground at G, has been retarded by the reſiſtance of the air. If from the nature of the ground, where the experiment is made, the vertical line K G be ſhortened, the initial velocity will be greater, and approach nearer the truth.

148. To determine the length of the movement of impulſion A M, in order to deduce from it the ſpace paſſed through by gravity; place vertically in M a butt L M N, lay the gun in a horizontal direction, or nearly ſo, and at M where the line of direction cuts the butt, draw tranſverſely a

horizontal line. Fire ſome ſhot into the butt as nearly as poſſible in the ſame direction, ſo that after each round the vertical diſtance M H between the horizontal line marked on the butt, and the hole H made below it by the ſhot, may be exactly meaſured: take the mean M H=S (144, No. 3) and ſubſtitute it in the formula $t=\sqrt{\frac{2MH}{32.18}}$; then by meaſuring the diſtance D L=A M=$q$, it will give the ſpace paſſed through in the ſame time by the movement of impulſion; and conſidering this ſpace, as uniformly paſſed through, $\frac{q}{\sqrt{\frac{2MH}{32.18}}}$ will be the initial velocity ſought (147). For example, let A M=200 feet, M H=6 inches, then $t=\sqrt{\frac{2\times\frac{1}{2}}{32.18}}=\frac{1}{6}$ of a ſecond, and $\frac{q}{\sqrt{\frac{2MH}{32.18}}}=\frac{200}{\frac{1}{6}}=1200$ the velocity ſought. The nearer the piece is brought to the butt, the ſhorter will be the time, and of courſe ſo much nearer to reality will be the initial velocity.

149. Theſe methods of determining the initial velocity may be applied to guns of all lengths and calibres. The velocities may be compared together when the experiments have been made under a conſtant ſtate of the atmoſphere; but as its frequent changes affect the exploſion of the powder, the following rules ſhould be obſerved:

1. To make the experiments under a mean ſtate of the atmoſphere both with reſpect to heat and moiſture; as the inflammation and exploſion of the powder are then much more uniform.

2. In order to know if the variation of the atmoſphere be the cauſe of any alteration that may occur, ſome rounds ſhould be fired from time to time from a gun of ſmaller calibre of a known initial velocity, as a wall-piece, placed very cloſe to a butt perfectly homogenous, to aſcertain whether the penetrations be regular.

3. If the reſults be conſtant, it will be a proof that the proceſs has been juſt in every particular, and that the

the ſtate of the atmoſphere has not varied. Any irregularity found in the reſults from the gun alone, will denote that ſome neceſſary precaution has been neglected: but if the reſults from both pieces are irregular, it will be proper to defer the proſecution of the experiments till another day, when the atmoſphere is more ſettled: in the mean time the utmoſt attention ſhould be paid to rectify any error in the apparatus, or in the mode of conducting the experiments.

4. If any interval of time be ſuffered to elapſe between the commencement and the proſecution of the experiments, and there be a difference in the initial velocity of the wall-piece, it will be proper to fire ſome rounds from the gun, in order to compare it with the preceding experiments. For example; if in the morning the initial velocity of a 32 pr. be 1383 feet, and that of the wall-piece 1696 feet; and in the afternoon the initial velocity of a 16 pr. be 1424 feet, while that of the wall-piece be only 1600; a few rounds ſhould be fired from the 32 pr. the initial velocity of which muſt be neceſſarily leſs than it was in the morning; ſuppoſe it to be 1315 feet: the following proportion will be formed, $1315 : 1383 :: 1424 : \frac{1383 \times 1424}{1315} = 1498$ which would be the initial velocity of the 16 pr. if the atmoſphere were in the ſame ſtate as in the morning. By this mode of operation, experiments made at any interval of time, at different ſeaſons, and under different ſtates of the atmoſphere, may be compared together with ſufficient accuracy.

150. If under a mean ſtate of the atmoſphere, with reſpect to heat, denſity, and moiſture, theſe experiments be made with guns of medium length loaded as before (143); it will be found, on firing them in a horizontal direction:

1. That with the largeſt charges the initial velocities are nearly as follows;

| Nature of Guns | | | Initial Velocities. |
|---|---|---|---|
| | *Prs.* | | *Feet.* |
| Shot | 32 | — | 1517 |
| | 16 | — | 1618 |
| | 8 | — | 1696 |
| | 4 | — | 1720 |

2. That

2. That with the medium charges they are very nearly as follows;

| Nature of Guns. *Prs.* | | Initial Velocities. *Feet.* |
|---|---|---|
| 32 | — | 1350 |
| 16 | — | 1416 |
| 8 | — | 1449 |
| 4 | — | 1467 |

3. That with the leſs charges (143) they will be about $\frac{1}{8}$ leſs than with the medium charge; for inſtance, a ſhot from a 32 pr. charged with $7\frac{1}{2}$lbs. of powder, will be impelled with an initial velocity of about 1180 feet, and a ſhot from an 8 pr. with $2\frac{1}{2}$lbs. of powder, with an initial velocity of about 1269 feet.

4. With the leaſt charges (143, No. 3) the initial velocities will be about $\frac{3}{10}$ leſs than thoſe with the medium charge; for inſtance, a ſhot from an 8 pr. charged with 1lb. 10 oz. of powder, will be impelled with an initial velocity of 1061 feet; and a ſhot from a 16 pr. with $2\frac{1}{4}$lbs. of powder, with an initial velocity of 1028 feet. It ſhould be recollected, that with ſmall charges, the leaſt difference in the mode of loading the the gun, makes a great alteration in the initial velocities, while with large charges its effects would be ſcarcely perceptible. The ſureſt mode of keeping all circumſtances as nearly equal as poſſible, is always to ram the wads well.

151. In experiments with three or four guns of the ſame calibre, but of different lengths, loaded as above (150, No. 2); the following rule will furniſh an approximation ſufficiently exact to draw from it concluſions applicable to practice. (Pl. 5, Fig. 15,) E B F repreſents the bore of a gun of any calibre; the medium charge of powder D and the wad S are ſo placed, that the ſhot A is diſtant from B three diameters of the bore F E: make $F C = \frac{2 A F}{3}$ and from the point C as centre, with the radius C A, deſcribe the arch A K P R, repreſenting the ſcale of initial velocities, by lines drawn perpendicularly from A F to the arch. To determine the initial velocity of a ſhot fired, for inſtance, from a long gun B L (66), loaded in the ſame manner (150, No.

No. 2); a normal line L Q drawn perpendicularly from the point L in the line A C, will correſpond to the relative initial velocity. To have the abſolute initial velocity, make the following proportions: the relative velocity F P of a gun of the length B F is to its abſolute velocity, as the relative velocity L Q of the gun B L is to its abſolute velocity; by the ſame method the initial velocity of a ſhot impelled from a gun of any length as B G may be found. The ſcale A K R would ſerve for longer guns, but it ſhould not be uſed (65).

152. Experiments made with a view to determine how much the initial velocities of ſhot are affected by the difference in the lengths of the guns, fired with different charges of powder, will be found to vary very little, from thoſe compuſed on the preceding principles.

153. From the theory of the inflammation of the powder in guns of cylindric bores, when all the grains are fired in the piece, the following modifications ought to occur;

1. In diminiſhing the charges in guns of the ſame calibre but of different lengths, the initial velocities of ſhot from the ſhort pieces ſhould correſpond more nearly thoſe from the longer ones, as the charges of the latter are diminiſhed; ſince the ſhot has its greateſt initial velocity, when in the ſhort piece the largeſt charge is all fired in the gun.

2. The greateſt velocity of a ſhot projected from a ſhort gun, is with the largeſt charge that is all fired in the gun: it is only in very ſhort guns that this does not hold good. (Treatiſe on Powder).

154. In computing theſe initial velocities, the guns have been ſuppoſed to be fired horizontally, or nearly ſo: but the velocities increaſe as the guns are elevated, which proves that the entire inflammation of the powder is accelerated by the greater reſiſtance oppoſed to the exploſion (Treatiſe on Powder). If a 32 pr. be fired with the medium charge (150, No. 2) at 20° elevation, the initial velocity will exceed 1350 feet, and increaſe very much, if fired at 36°.

In the following chapter will be ſhewn the method of determining the initial velocities of ſhot fired from guns at high elevations.

CHAP.

## CHAP. II.

### Of the Curve described by Cannon Shot.

155. THE charges of powder for common ſervice have been already mentioned (150, No. 1 and 2,; the objects againſt which they are directed ſhould not be very high; and to fire with effect, be leſs than 1000 yards diſtant: even then the air's reſiſtance to the ſhot is very great, though its effects on the gravitating principle be almoſt inſenſible. When the line of deſcent is leſs than 260 feet, and the time of the ſhot's flight not more than 4 ſeconds, the ſhot's path is a curve of the ſecond kind; ſo denominated to diſtinguiſh it from the curve of the fourth kind, where the movements of impulſion and gravitation are both greatly affected by the reſiſtance of the air. In the Treatiſe on Powder, it was demonſtrated that the air's reſiſtance conſiderably retarded the movement of leaden bullets; and in the laſt chapter on hydroſtatics, the air's reſiſtance to military projectiles is expreſſed in pounds. In this chapter we propoſe to determine the law by which the air retards the movement communicated by the impelling power, in another manner, viz. directly by its forces.

156. To ſolve this problem, we muſt find experimentally *the ſcale of ſpaces paſſed through during the time of an impulſive movement, retarded by the medium that the ſhot flies in:* the initial velocities may be found by the method expreſſed in the laſt chapter. Hitherto we have only conſidered the effects of the alterations in the ſtate of the atmoſphere, on the inflammation and exploſion of the powder, and conſequently on the initial velocities of ſhot; we will now examine how far they can vary the air's reſiſtance to the ſhot, and render the former concluſions erroneous.

The barometer will in ſome degree point out any changes that may take place, and for greater accuracy, two ſmall guns may be fired againſt a homogenous butt, at any diſtance not leſs than 160 yards; to aſcertain by the one, if the initial velocities be conſtant (149); and by the other, if the air's reſiſtance continue the ſame. An elevated ſhot ſhould be choſen for theſe experiments, where, the gun laid horizontally, may be directed to the right or left, that the firſt grazes

of

of the ſhot may ſeverally be on planes one below the other. Let theſe different planes be 4, 16, 36, 64, 100, and 144 feet below the gun's axis; then the time of the ſhot's flight through the ſeveral ſpaces will be $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, and 3 ſeconds; thus, the equation of the ſcale will be more eaſily found.

Then, with a charge that gives a known initial velocity, fire ſome rounds towards the place, 4 feet below the plane of the gun, in order to obtain the mean of the horizontal ranges (144, No. 3) which may be called $d\,g$ (Pl. 5, Fig. 17): turn the gun to the place 16 feet below its plane; fire ſome rounds, and call the mean $r\,p$; let $n\,b$ be the mean to the place 36 feet, and K $y$ to the place 64 feet below the gun. On the directrix $a$ K ſet off the times $t = \sqrt{\frac{2\,S}{32.\,18}} = a\,d$, $a\,r$, $a\,n$, $a$ K, correſponding to the lines of deſcent 4, 16, 36, and 64 feet; and erect from the points $d$, $r$, $n$, K, perpendiculars to the line $a$ K, reſpectively equal to the means of the ranges already found; the line $a\,g\,p\,b\,y$ paſſing through the extremities of theſe perpendiculars, will be the ſcale of ſpaces paſſed through during the times of the retarded movements of impulſion.

157. If no convenient place can be found for this purpoſe the experiments may be made in another manner: on the ſide of a hill or mountain as (Pl. 5. Fig. 16) H L A, at the bottom of which is a horizontal plain M Z, chuſe the ſtations A, L, H, of different heights; and from them fire the gun in the horizontal directions A K, L F, H X: then the perpendicular lines G K, P F, Z X will be ſpaces that the ſhot fall through by the power of gravity. The longeſt of theſe lines ſhould be leſs than 260 feet, that the reſiſtance of the air may not ſenſibly affect the gravitating power, and that the difference of the heights may not occaſion any alteration in the inflammation of the charge. From each of the points A, L, H, fire ſome rounds with charges of which the initial velocities are known, in order to obtain the mean of the ranges (144, No. 3); then ſuppoſing that from the point A the mean of ranges is = D G, from the point L = R P, from the point H = N Z; mark upon the directrix $a$ K (Pl. 5, Fig. 17.) the times correſponding to the vertical lines G K, P F, Z X; erect from the points $d$, $r$, $n$, the normal lines $d\,g$, $r\,p$, $n\,b$ equal to the means of ranges already found,

and

and drawing a line through the points *a g p b y*, it will be the ſcale of ſpaces in the times of the retarded movements of impulſion.

158. Having conſtructed this ſcale (156, 157), the reſult of the experiments ſhould be examined to ſee that there be no error, and as it is the ſcale of a retarded movement, it ſhould have the properties expreſſed in the treatiſe on moving bodies: in the firſt place, the line *a g p b y* ſhould be a curve concave towards the directrix, and the differences *p m*, *b o*, *L y* between the ordinates, ſhould decreaſe in a regular progreſſion from *a* to *y*; wherefore, if the ſcale be a right line, or a curve convex toward the directrix, it is a proof that ſome errors have been committed in making the experiments, or in taking the reſults. But if they differ a little in one or two points only, it is immaterial, ſince ſmall errors are inevitable. when this occurs, the differences ſhould be judiciouſly corrected. To this end, deduct the ſecond differences from the firſt: and if the reſults be ſtill erroneous, take the third differences; in the latter, the leaſt irregularity in carrying on the experiments will conſiderably diſturb the order of progreſſion. To ſet this matter in a clear point of view, ſuppoſe the following to have been the reſult of the experiments.

Spaces paſſed through by the Shot from the impulſive motion in correſponding times.

| | | | Differences. | | |
|---|---|---|---|---|---|
| *Seconds of Time:* | *Feet.* | | *Firſt.* | *Second.* | *Third.* |
| 1 — | 1302 — | | — | — | — |
| 2 — | 2394 — | | 1092 | — | — |
| 3 — | 3310 — | | 916 | 176 | — |
| 4 — | 4082 — | | 772 | 144 | 32 |
| 5 — | 4730 — | | 648 | 124 | 20 |
| 6 — | 5284 — | | 554 | 94 | 30 |

If no error be perceptible in the firſt; but in the ſecond, the progreſſion does not decreaſe regularly, and in the third the difference after decreaſing from the firſt term 32 to the ſecond 20, increaſes from the ſecond term 20 to the third term 30, to correct theſe errors, let the reſults be modified as below; then will all the differences decreaſe in a regular progreſſion and be ſufficiently accurate.

Reſults

| | Reſults modified. | | Differences. | | |
|---|---|---|---|---|---|
| *Seconds of Time.* | *Feet.* | | *Firſt.* | *Second.* | *Third.* |
| 1 — | 1302 — | | — | — | — |
| 2 — | 2394 — | | 1092 | — | — |
| 3 — | 3310 — | | 916 | 176 | — |
| 4 — | 4082 — | | 772 | 144 | 32 |
| 5 — | 4736 — | | 654 | 118 | 26 |
| 6 — | 5292 — | | 556 | 98 | 20 |

159. When the ſcale thus modified has the properties expreſſed in the preceding paragraph, we ſhould proceed to examine whether the reſults are juſt and concluſive.

FIG. 17. For this purpoſe, if *a g p b y* be an equation of this ſcale, and *i f b e* the equation of the ſcale of velocities in correſponding times (Treatiſe on Moving Bodies), which ſhould be a curve-line convex toward the directrix, whoſe greateſt ordinate *a i* drawn from *a* the beginning of the times muſt be equal to the initial velocity of the ſhot, the other ordinates will decreaſe in proportion as the times increaſe, and the ſcale *i f b e* will approach the directrix, and touch it when the ſhot has entirely loſt its impulſive motion. For example, ſuppoſe the equation of the curve *a g p b y* to be $q^2+nq=mt$; where $q$ expreſſes the ſpace paſſed through by the ſhot from the impulſive motion, $t$ the time; $m$ and $n$ are two conſtant quantities which expreſs the initial velocity: if from this equation be deduced the equation of the velocities in the times, $U=\frac{m}{2\sqrt{\frac{n^2}{4}+mt}}$ will have all the properties that belong to the retarded motion; whence it may be inferred that the experiments have been properly conducted.

Fig. 17. If on the contrary, the equation for the ſcale *a g p b y* be $pt^2=q^2$, where $p$ is a conſtant quantity, and the ſcale of the velocities in the times be deduced; $U=\frac{2pt}{3q^2}$, where $t=o$; the velocity is then equal to $o$, which is a manifeſt abſurdity, ſince it muſt be equal to the initial velocity of the ſhot. Again, if $pt-t^2=q^2$ be the equation for *a g p b y*

$by$ where $p$ is a conſtant quantity; and the equation for the ſcale of velocities in the times be deduced, $U=\frac{p-2t}{2\sqrt{pt-t^2}}$, which is an abſurdity; ſince when $t=o$, the initial velocity is infinite.

160. In fine, if the ſcale of velocities in the times be conformable to the retarded movement, the ſcale of the air's reſiſtance to the ſhot at each inſtant may be deduced from it; if this ſcale be a convex curve, and its greateſt ordinate at $a$ with a progreſſive ſeries analogous to the ſcale of velocities, it will be a certain proof that the reſult is juſt: but ſhould the ſcale of reſiſtances not have the requiſite properties, the reſults muſt be faulty. From the equation of the ſcale of velocities $U=\frac{m}{2\sqrt{\frac{n^2}{4}+mt}}$, may be deduced the ſcale of preſſures $=p$; then $p=\frac{m^2}{n^2+4mt\times\sqrt{\frac{1}{4}n^2+mt}}$ is an equation that combines all the requiſite properties.

161. The reſiſtance of the air to the rapid movements of projectiles depends not only on the actual denſity of the atmoſphere, but on the condenſation of the air before the projectile, whenever its velocity exceeds 1300 feet; for a vacuum is then formed behind the ſhot, which becomes ſo much the greater as the velocity exceeds 1300 feet.

After repeated experiments and obſervations on this ſubject, it appears that when guns are fired with charges that give an initial velocity of about 1300 feet, the formula $q=\frac{crt}{r+t}$ will expreſs the retarded motion of impulſion with ſufficient exactneſs for practice, whenever the extent of the movement is leſs than 1350 yards: but if the initial velocities be much greater or leſs than 1300 feet, this formula will not ſerve. The letter $q$ expreſſes the line of projection, which in ſhot impelled horizontally always correſponds to the length of the range; $c$ the initial velocity of the ſhot, $t$ the time that it takes to paſs through the ſpace $=q$; and $r$ a number proportioned to the diameters of the ſeveral ſhot; this number is combined with the actual denſity of the atmoſphere,

moſphere, and its value may be found by experiment. The diameters of the ſhot are as follows:

| Nature of Guns. | Diameter of Shot. |
|---|---|
| *Pr.* | *Inches.* |
| 32 — — — | 5.760 |
| 16 — — — | 4.566 |
| 8 — — — | 3 653 |
| 4 — — — | 2.881 |

If from the denſity of the air, $r=12$ in a 32lb. ſhot, the value of $r$ for ſhot of other diameters may be found by analogy; hence in a 16lb. ſhot, $r=9.5$; in an 8lb. ſhot, $r=7.6$; and in a 4lb. ſhot, $r=6$. If from the denſity of the air, in a 32lb. ſhot $r=14$; then in a 16lb. ſhot $r=11.1$; in an 8lb. ſhot, $r=8.8$; and in a 4lb. ſhot $r=7$.

For example, ſuppoſe from the denſity of the atmoſphere $r=12$ in a 32lb. ſhot, of which the initial velocity is 1349 feet $=c$; and the value of $q$, the ſpace paſſed through with this ſame velocity in different times, be required: by ſubſtituting theſe data in the formula; in two ſeconds of time, $q=\frac{1349\times 12\times 2}{12+2}=2312$ feet; and in three ſeconds, $q=\frac{1349\times 12\times 3}{12+3}=3237$ feet. If the initial velocity be 1517 feet, in three ſeconds the line of projection is 3640 feet.

In a 16lb. ſhot with an initial velocity of 1416 feet, the line of projection in two ſeconds is $q=\frac{1416\times 9.5\times 2}{9.5+2}=2402$ feet; and in 4 ſeconds is 3985 feet.

In an 8lb. ſhot with an initial velocity of 1696 feet, the line of projection in 3 ſeconds is $=\frac{1696\times 7.6\times 3}{7.6+3}=3648$ feet.

In a 4lb. ſhot, with an initial velocity of 1550 feet, the line of projection in 4 ſeconds is 3720 feet.

Suppoſing the atmoſphere to become leſs denſe, ſo that in a 32lb. ſhot $r=14$; then if the initial velocity be 1433 feet, the line of projection in 4 ſeconds is 4458 feet.

In a 16lb. ſhot, with an initial velocity of 1534 feet, the line of projection in 2 ſeconds is 2599 feet.

In an 8lb. ſhot, with the initial velocity of 1450 feet, the line of projection in 1 ſecond is 1302 feet.

In a 4lb. ſhot, with the initial velocity of 1920 feet, the line of projection in 3 ſeconds is 3612 feet.

162. If from the equation $q=\frac{crt}{r+t}$ be deduced the ſcale of velocities V in the times, (159) $V=\frac{cr^2}{r+t^2}$, which will give the remaining velocities, after the ſhot has paſſed through the ſpace $q$ in the time $t$. For example, ſuppoſe from the denſity of the air $r=14$ in a 32lb. ſhot; then if the initial velocity be 1349 feet, the remaining velocity after 4 ſeconds will be $V=\frac{1349\times 14^2}{14+4^2}=816$ feet. A 16lb. ſhot, with the velocity of 1416 feet, will have a remaining velocity after 3 ſeconds of 877 feet.

The remaining velocity of an 8lb. ſhot, with the initial velocity of 1686 feet, will after 4 ſeconds be 796 feet. The remaining velocity of a 4lb. ſhot, with the initial velocity of 1467 feet, will after 2 ſeconds be 887 feet.

Again, from the ſtate of the atmoſphere $r=12$; then the remaining velocity of a 32lb. ſhot, with the initial velocity of 1517 feet, will after 2 ſeconds be 1114 feet: a 16lb. ſhot, with the initial velocity of 1484 feet, will after 4 ſeconds be 734 feet: an 8lb. ſhot, with the initial velocity of 1686 feet, will after 3 ſeconds be 866 feet; and a 4lb. ſhot, with the initial velocity of 1600 feet, will after 2 ſeconds be 900 feet.

163. The problems of the curve of the ſecond kind (155) may be reſolved by the formulas $q=\frac{crt}{r+t}$, $S=\frac{32.18t^2}{2}$.

(Pl. 5. Fig. 16.) Given the initial velocity $=c$ of a 32lb. ſhot fired from A with the horizontal direction A K, to determine by experiment the value of $r$. Suppoſe that the ſhot touch the ground in the point G of the plane D Z, as the line of projection $AK=DG=q$, and the line of deſcent K G are known; by ſubſtituting this laſt value in the formula $S=\frac{32.18t^2}{2}$, it will give $\sqrt{\frac{2KG}{32.18}}=t$, and by ſubſtituting the

the known values of $q$, $c$, $t$ in the formula $q=\frac{crt}{r+t}$, the value of $r$ will be found. For example; let $c=1517$, and A K be found by experiment$=2655$, and K G$=64$ feet; then $t=2$; and consequently $r=\frac{qt}{ct-q}=\frac{2655\times 2}{1517\times 2-2655}$ $=14$. Having thus found the value of $r$ for the 32lb. shot, it may be found for the 16, 8, and 4lbs. from the proportion of the diameters of the shot (161).

164. The value of $r$ being given, to find by experiment the initial velocity of a shot fired in any direction. Suppose in the first place, that when the gun is fired in a horizontal direction A K, the first graze of the shot is at G: the line of projection and the line of descent being known, by substituting this last value in the formula $S=\frac{32.18\,t^2}{2}$ the time of flight will be found: the substitution of which in the other formula will give the value of $c$. For example, if an 8lb. shot be fired in the same resisting medium as in the preceding paragraph, $r=8.8$: and supposing A K$=3478$ feet, and K G$=144$ feet, then $t=3$; and consequently $c=\frac{q\times\overline{r+t}}{rt}=\frac{3478\times\overline{8.8+3}}{\overline{8.8\times 3}}=1554$.

Suppose, in the second place, (Pl. 6, Fig. 18) that the gun be fired in a direction A M, forming with the horizon the angle M A R, whose value is known; and, that the shot strike the ground in H: by measuring the horizontal distance A R, the line of projection A M and the line of descent M H will be found. If M H be less than 260 feet, the initial velocity will be greater (154), than if the gun had been fired with the same charge in a horizontal direction. Let M H$=100$ feet, then $t=2\frac{1}{2}$: let A M$=2920$, and the shot be a 4 pr. fired in the same resisting medium as above, $r=7$; consequently $c=1585$.

165. To determine the angle of elevation (Pl. 6, Fig. 19) D A F under which a shot with a charge that gives a known initial velocity$=c$ will from the point A strike the object B, above or below the horizontal line A F.

Draw the perpendicular line B D, and suppose D A to be the direction in which the gun must be fired. Then as the

angle B A F and the ſide A B in the [illegible] triangle B F A are known, the ſides A F, P [illegible] found; call A F $=m$, B F $=n$. Since the [illegible] $=$ S $=\frac{32.18t^2}{2}$, and the line of projection A D $=$ [illegible] $\frac{crt}{r+t}$ D F $=\frac{32.18t^2}{2}\pm n$, according as the point B is above or below F. As in the rectangled triangle A F D, $\overline{AD}^2=\overline{AF}^2+\overline{DF}^2$, by ſubſtituting the analytical values we ſhall have the following equation, $\frac{c^2r^2t^2}{r^2+2rt+t^2}=m^2+\frac{1035t^4}{4}\pm 32.18nt^2+n^2$: whence may be deduced the value of $t$. If the point B coincide with the point F and the butt be in the plane of the gun, the value of $n=o$, and may be ſtruck out of the equation: the value of $t$ being thus known, thoſe of B D and A D may be afterwards found, which will give the angle of elevation D A F that was ſought.

166. (Pl. 6. Fig. 20.) From the point B to hit the object L ſituated in the ſame plane as the gun: the value of $t$ may be found in the following manner with ſufficient accuracy for practice; ſince even when the amplitude of a 32lb. ſhot is 1348 yards, the difference in the elevation H B L will not be $\frac{1}{2}$ ſecond.

The diſtance B L between the gun and the object, may be conſidered as the line of projection $q=\frac{crt}{r+t}$, and ſubſtituting in this formula, the data $q$, $c$, $r$, the value of $t$ may be found; which being again ſubſtituted in the formula S $=\frac{32.18t^2}{2}$ gives the value of S for the line of deſcent L G: draw the line B G; then, in the rectangled triangle B L G, the angle G B L will be known: make the angle L B H equal to the angle G B L; B H will then be the direction in which the gun ſhould be fired to ſtrike the point L. For example, if B L be 560 yards, and a 32 pr. be fired with the medium charge of powder, $c=1350$ feet (150); and from the reſiſtance of the air $r=12$: by ſubſtituting theſe numbers in the firſt formula, $1680=\frac{1350\times 12t}{12+t}$, and conſequently

ſequently $t=1.4$ again ſubſtituting this value in the ſecond formula $S=\frac{32.18\times\overline{1.4}^2}{2}=31$ feet $=LG$, and finding trigonometrically $\angle GBL=1^\circ 3'$, the $\angle LBH$ that was ſought is alſo $1^\circ. 3'$.

167. From the preceding theory, (Pl. 6, Fig. 20) it will be eaſy to determine the value of $r$ and the initial velocity $=c$, when theſe two quantities are unknown, by firing only two rounds. Fire a gun in any direction B D, provided that the line of deſcent be leſs than 260 feet; and, ſuppoſing the ſhot to ſtrike the ground in E, find geometrically the line of projection $BD=q$, and the line of deſcent $DE=S$; and, by the formula $S=\frac{32.18\,t^2}{2}$ find the time: then ſubſtitute theſe values in the equation $BD=q=\frac{c\,r\,t}{r+t}$. If the gun be again fired with the ſame elevation, and exactly loaded as before, but turned to the right or left, ſo that the ſhot may ſtrike another point G, higher or lower than the former one E; having found geometrically the line of projection $BK=q$, and the line of deſcent KG, find the value of $t$, and ſubſtituting it in the equation $BK=q=\frac{c\,r\,t}{r+t}$; theſe two equations will give the values of $c$ and $r$.

Suppoſe, in the firſt inſtance, that $BD=1820$ feet, and $DE=36$ feet; and, in the ſecond, $BK=3237$ feet, and $KG=144$ feet: then ſubſtituting theſe numbers in the firſt formula, $1820=\frac{c\,r\times\frac{3}{2}}{r+\frac{3}{2}}$; and again in the ſecond, $3237=\frac{c\,r\times 3}{r+3}$; from theſe two equations, $c=1348$ feet, and $r=12$.

In firing againſt the height, R H (Pl. 6, Fig. 18) having fired one round from A, in the direction A M; the gun ſhould be advanced to L, or retired to P; and, from one of theſe two ſtations, a ſecond round fired with the ſame elevation; ſince whenever it is altered, the initial velocities differ (154).

168. The elevation AD, (Pl. 6, Fig. 21) and the initial velocity $=c$ being given, and the value of $r$ and of the line of deſcent B D being known, to find the direction

and the quantity K B of compound velocity, with which the ſhot ſtrikes the point B.

From B D deduce the value of $t$; and by the formula $u = 32.18\,t$ of the velocities in the times through the movement of gravitation (Treatiſe on Moving Bodies 283) find the value of $u$, which ſet off from B to H: from the point H draw H K parallel to D A, and by the formula $V = \frac{cr^2}{r+t^2}$ (162) find the remaining velocity $= V$ ariſing from the movement of impulſion after the time $t$; then by ſetting off its value from H to K; and drawing the right line B K, it will give the direction, and the quantity of compound velocity which the ſhot has at the point B. Let B D $= 144$ feet, then $t = 3$, and $u = 32.18 \times 3 = 96 = $ B H; and ſuppoſe $c = 1350$ feet and $r = 13$; then $HK = V = \frac{1350 \times 13^2}{13+3^2}$ $= 891$ feet; and ſince the $\angle$ B H K is equal to the $\angle$ B D A which is known, the direction will be found, and alſo the quantity of compound velocity B K.

169. A combination of the formulas $S = \frac{32.18\,t^2}{2}$, $q = \frac{c\,r\,t}{r+t}$ (163) will give the equation $S = \frac{32.18}{2} \times \frac{q^2 r^2}{c^2 r^2 - 2cr q + q^2}$ appertaining to the curve of the ſecond kind (155), by means of which all the preceding problems may be ſolved. For example, if the initial velocity be known, and the value of $r$ of a ſhot of given calibre be required; it will be ſufficient to fire a round in a direction A D correſponding to the given velocity; and ſuppoſing the ſhot ſtrikes in B, by finding geometrically the values of the line of projection A D $= q$, and the line of deſcent B D $= S$, and ſubſtituting them in the equation of the curve, it will give the value of $r$. Again, to find the initial velocity, and the value of $r$; it will be neceſſary to make two experiments with the ſame charge, and at the ſame elevation (167); in each of them the values of the lines of direction and deſcent muſt be found and ſubſtituted in the formula $S = \frac{32.18}{2}$

$\frac{32.18}{2} \times \frac{c^2 r^2}{cr-q^2}$, whence the values of $c$ and $r$ may be deduced.

The application that will be made in the following chapters of the doctrine here laid down on the unequal movement of impulſion (161) will enable us with a moderate ſhare of diſcernment, to derive the greateſt advantages (141) from the uſe of artillery.

170. To determine the curve of the fourth kind; when the reſiſtance of the air to the two unequal movements that conſtitute it is great, and the ranges are long; it is neceſſary to make a courſe of experiments, which from the continual variation in the ſtate of the atmoſphere, and other circumſtances, are very tedious, and require much accuracy and intelligence in thoſe that carry them on. As I had not an opportunity of making all the experiments I deemed ſatisfactory on this head, I have here only laid down the fundamental principles, that others may be enabled the more eaſily to proſecute the enquiry. Among the different methods that may be taken to determine the laws of this curve (156), the following appears the beſt.

Chuſe an elevated ſituation, where the gun may be turned to any ſide; ſo that the ſhot may ſeverally ſtrike points, one below the other, in ſuch a proportion that the lines of deſcent may be 848, 1696, 3046, 5088 feet. From this ſpot fire ſeveral rounds in a horizontal direction towards the ſame object, with a charge that gives a known initial velocity, in order to obtain a medium of horizontal ranges and of lines of deſcent. Perſons ſhould be ſtationed at different parts with ſecond watches, to reckon exactly the time that the ſhot takes from the inſtant they ſee the ſmoke of the gun, till it touch the ground. Having found the mean of the two movements of impulſion and gravitation, turn the piece towards another object, in order to obtain a different medium, then towards a third and a fourth, with the ſame precautions as before.

Theſe experiments ſhould be repeated with a gun of a very different calibre, with the ſame care and attention (156), that the reſults may not be affected by the variations of the atmoſphere. Shot much lighter than the common ſhot may be made for the occaſion, by ſuſpending in the center of the mould a ſphere of well-tempered clay, which will be thus

completely enveloped by the melted metal; the reſiſtance of the air to theſe projectiles will be much more ſenſible. If this hollow ſhot be to a ſolid one of the ſame diameter, as the weight of a ſhell full of powder is to a ſhell of the ſame diameter caſt ſolid, the reſults may be applied to mortars in a much more ſimple manner.

After the experiments, conſtruct two ſcales for each gun: one for the ſpace paſſed through during the time of a retarded movement of impulſion; the other for the movement unequally accelerated by gravity. The laſt ſcale ſhould give a curve convex towards the directrix. The two ſcales may be analyſed in the manner above ſhewn (158, 159, 160); and if the experiments have been made with care, the equation of each movement will be ſo expreſſed as to ſerve for all the different ſtates of the atmoſphere.

171. While the ſtate of the atmoſphere remains the ſame, the reſults of the experiments (170) will be concluſive, if they have been carried on with proper attention: but the ſame inference muſt not be drawn in the former caſe (157). For if a gun be fired from the different heights A, L, H, (Pl. 5, Fig. 16) and the lines of deſcent G K, P F, Z X, be very conſiderable as 848, 1696, 3046, and 5088 feet, the reſults will be falſe and inconcluſive, even if there be no alteration in the ſtate of the atmoſphere;

1. Becauſe ſhot fired from different heights are oppoſed by air of different denſities; the law therefore of the inflammation and exploſion of powder is altered, though the quantity be the ſame: of courſe the initial velocities will differ.

2. The lines of deſcent G K, P F, Z X, and the lines A K, F L, H X, which expreſs the movement of impulſion, traverſe in an inverſe order the air which is of different denſities at different heights; whereas by firing always from the ſame place H (170), the ſhot will at the firſt graze ſtrike the points M, B, E, T, with correſponding lines of deſcent; and traverſe the air in the natural order; the lines which expreſs the movement of impulſion will be in the direction H X.

To aſcertain the modifications that take place in the inflammation and exploſion of powder, and in the reſiſtance of the air to projectiles, owing to alterations in the ſtate of the atmoſphere, the following experiments may be made: Let a muſquet be fired very cloſe to a butt in the bottom of a valley;

a valley; and another be fired with an equal quantity of powder of the ſame quality againſt the ſame butt, at the diſtance of 675 feet: at the ſame time let another perſon, at a place 5000 or 6000 feet above the former ſituation, diſcharge a bullet from a muſquet of the ſame calibre equally charged, and at the ſame diſtances as the former one, againſt a butt equally homogenous and conſiſtent: the penetrations will be much deeper from the muſquet fired near the butt at the foot of the mountain, than from that fired near the butt at the higher ſituation; but will be much leſs at the diſtance of 675 feet, than from the upper one at 675 feet. Theſe effects were ſo ſenſible in the campaigns of 1743, 1744, and 1747, in the ALPS, that there were days when the muſquets fired at the top of the mountains ranged $\frac{1}{7}$ more than the ſame muſquets at the bottom: ſometimes the mountains were enveloped in thick clouds, while the vallies beneath were perfectly clear; at other times the atmoſphere in the vallies was loaded with vapour, while thoſe on the heights enjoyed a cloudleſs ſerenity: in ſhort, ſo great and frequent were the alterations, that the experiments of one day bore no analogy to thoſe of the next.

172. To determine in another manner the law of each of the unequal movements that conſtitute the curve of the fourth kind; let a gun be frequently fired from a horizontal plain P A K, (Pl. 6. Fig 18.) at the foot of a mountain K I H, with the ſame elevation K A M, and with a charge that gives a known initial velocity. Fire ſome rounds from A, ſo that the medium of the lines of deſcent may be from 600 to 700 feet: fire again from P, at a greater diſtance from K the foot of the mountain, that the ſhot falling in I, the lines that expreſs the movements of impulſion and gravitation, may be longer: remove the guns ſtill farther from K, and fire as before; and, having taken the mean reſult, retire the gun to a ſtill greater diſtance from the mountain, ſo that the ſhot falling on the plane P L, may give the longeſt lines of projection and deſcent poſſible, under theſe circumſtances; always uſing a ſecond watch to mark the time of flight of the ſhot; and, taking every precaution to know whether the ſtate of the atmoſphere remain the ſame. From theſe reſults two ſcales applicable to the uſes before expreſſed (170) may be conſtructed. Experiments conducted in this manner cannot be very erroneous, but, their reſults are more complicated than the others, (170) ſince

ſince the ſhot in aſcending, paſſes continually from a denſe to a more rarified medium, while the reverſe takes place when the ſhot deſcends.

## CHAP. III.

### OF THE EFFECTS OF CANNON SHOT ON WORKS.

173. THE uſe of heavy artillery (64) is to ruin and demoliſh permanent fortifications and works.

In the attack of fortreſſes, 32 prs. are uſed for battering in breach, when the ramparts are of great ſolidity; but, from the great expence attending theſe heavy guns, and the difficulty of tranſporting them, 16 prs. ſerve for diſmounting the artillery in the outworks, and beating down the defences. For richochet and hot-ſhot firing, 4 and 8 prs. are uſed, as they require leſs ammunition, and fewer men to work them.

In the defence of places, againſt which the beſieger can eſtabliſh any number of batteries he pleaſes, the proportion of 32 prs. ſhould not exceed a third of the whole number of guns in the garriſon; as 8 prs. will ſerve for firing againſt the opening of the trenches, and 16 prs. againſt the approaches: but, if the ſituation of the ground be ſuch, that the artillery of the place has a decided ſuperiority over any batteries the beſieger can erect; then, to take full advantage of this circumſtance, the number of 32 prs. ſhould be increaſed: long 4 prs. will keep the enemy in reſpect around the place, and a few ſhort light pieces (66) may be held in readineſs for making ſallies.

174. To uſe fire-arms to the greateſt advantage, the effect of each ſhot ſhould be obſerved: (141) for this purpoſe;

1. The guns and carriages ſhould be conſtructed with the utmoſt accuracy.

2. The guns ſhould be ſerved with care and judgment, and placed at a proper diſtance from the objects intended to be battered.

175. In the former part of this treatiſe, the principles of the beſt conſtruction for guns were fully explained: but, as an officer is ſometimes obliged to uſe guns defective in ſome material point, he ought to conſider by what expedient he can

can beſt remedy the defect: the charge ſhould be leſſened, when it proceeds from the want of proper weight in the gun, or of a due thickneſs of metal in the breech.

The knowledge of an artilleriſt ſhould be both theoretical and practical: to aſcertain the nature of the curve deſcribed by a projectile, develope the cauſes that influence its formation; thence deduce rules applicable to the various caſes that occur on ſervice, and be able in the beſt and moſt expeditious manner, to repair any accident that may happen, is the part of the theoriſt, and of the officer. The non-commiſſioned officers and ſoldiers are inſtructed in the part purely practical: they are taught

1. To load the guns in a regular and uniform manner, and to ram the wads when the ſame charge is uſed, with equal force; a neglect in this point is the cauſe of great irregularity, particularly when the guns are depreſſed.

2. In laying the gun, to remove every obſtacle that can tend to derange the firing.

3. Having by two or three rounds aſcertained the direction for hitting the object, to continue it without variation.

176. That the gun may be placed at a proper diſtance from the object (174, No. 2); the ſhot's path muſt be conſidered, and allowance made for every circumſtance that can affect the range: the relative ſize and poſition of the object muſt be particularly attended to; for, when it is much higher than the gun, though very diſtant and narrow, it is more eaſily hit, than when lower and of greater extent; ſo that the lower the object is, the nearer the gun muſt be brought to it. In the attack and defence of places of low profile, the height of the works againſt which the fire is directed in the firſt part of the attack, does not exceed 7 feet, as the parapets, the exterior of the embrazures, the heads of ſaps, &c. The greateſt diſtance at which guns ſhould be fired againſt ſuch low objects, has been fixed in our military treatiſes, at 680 yards.

177. After hitting the object, the next point is to conſider the degree of force requiſite to overcome its reſiſtance: for, if this be ſuperior to the impetus of the ſhot, no effect will be produced; and, when greatly inferior, it may be ſometimes proper to diminiſh the force of the projectile, in order to produce a greater effect, and avoid ſpoiling the guns

guns before the ſiege is over, by firing with large charges. The following conſiderations may perhaps aſſiſt an officer commanding a battery, in forming his judgment on this occaſion.

1. The largeſt charges are only uſed when a great force is required, and exactneſs in firing is not abſolutely neceſſary; as battering in breach from the creſt of the glacis. But, in firing from great diſtances to diſmount the enemy's guns, batter the trenches, heads of ſaps, or other low works, the medium charges are ſufficient, that the violence of exploſion may not produce irregularities (7, 8, 9).

2. The leſs, and even the leaſt charges will ſerve for battering towns or villages ſurrounded with a ſingle wall, unſupported with a rampart of earth; ſince a ſhot impinging on a thin wall with great force, makes a hole without ſhaking the contiguous parts: thus it requires a greater number of rounds with large charges to demoliſh them, than if the charges were diminiſhed. Should the ſituation of the ground permit the gun to be laid on an oblique direction at the object, the medium, and even the largeſt charges may be uſed: in this caſe the effects of the ſhot are in the ratio of the angles of incidence.

178. The force of the direct ſhock of hard bodies, is calculated from their maſs multipled into their velocity; and the force of the oblique ſhock, by multiplying the former product by the right ſine of the angle of incidence, divided by the whole ſine (Treatiſe on Moving Bodies). If the force $=f$; the weight of the ſhot $=m$, the velocity with which it impinges $=V$, the right ſine of the angle of incidence $=a$; then $f = m\,V \times \frac{a}{\text{whole ſine}}$ is the general formula in which the fraction $\frac{a}{\text{whole ſine}}$ is equal to unity in the direct ſhock.

If the value V of the remaining velocity (162) be found, the impetus with which ſhot of the ſame or different diameters impelled with different intial velocities, impinge on objects at different diſtances, may be compared. For inſtance, let the diſtance between the gun and the object be expreſſed by the line of projection, and in a 32 pr. $r = 12$: then

then in the direct ſhock, the force with which a 32 lb. ſhot with an initial velocity of 1350 feet, impinges on an object placed very cloſe to it, is to its force at 4056 feet, as 1350 : 759 : and the force with which a 16lb. ſhot, with an initial velocity of 1416 feet, ſtrikes an object at the diſtance of 932 feet, is to its force at 3229 feet, as 1226 : 817. On comparing in the ſame manner ſhot of different diameters, it appears, that the force with which a 32lb. ſhot, with an initial velocity of 1350 feet, ſtrikes an object at the diſtance of 330 feet, is to the force of a 4lb. ſhot, with an initial velocity of 1467 feet, at the diſtance of 3520, as $32 \times 1300 : 4 \times 528$ ; that the force of a 16lb. ſhot, with an initial velocity of 1416 feet, at the diſtance of 3886 feet, is to the force of an 8lb. ſhot, with an initial velocity of 1449 feet, at the diſtance of 350 feet, as $16 \times 716 :: 8 \times 1361$. If under ſimilar circumſtances, the ſhocks be oblique, ſo that with a 16lb. ſhot the angle of incidence be 20°, and with an 8lb. ſhot 75°, the two ſhocks will be to each other : : $16 \times 716 \times 34202 : 8 \times 1361 \times 96592$.

179. In the preceding paragraph it was ſuppoſed, that the compound velocity B K of the ſhot, when it impinges on an object, was equal to the remaining velocity H K, which is in the ratio of the retarded motion of impulſion : this is the caſe not only in this particular inſtance, but in all others that do not admit of geometrical preciſion. Nevertheleſs, on aſcertaining the greateſt difference that can be between theſe two velocities, in the common ſervice of guns, we ſhall find it to be too inconſiderable to occaſion any material error; for, if the value of the compound velocity B K be determined (168), the gun having been fired at the higheſt elevation the carriage will admit of, B K is leſs than H K in the proportion of about $\frac{3}{4}$ in the 100 ; that is B K : H K : : 397 : 400 ; and if the gun be depreſſed as much as poſſible, B K will exceed H K in the proportion of about $\frac{1}{8}$ in the 100 ; that is B K : H K : : 801 : 800.

180. Among the ſeveral works againſt which cannon are fired ; there are ſome which do not yield to the moſt violent ſhocks ; and others of very ſlight reſiſtance. Of the firſt kind are thoſe cut out of the ſolid rock, the hardneſs of which joined to the coheſion is ſuch, that the moſt violent ſhocks cauſe no diſunion in the parts. If the weight of the ſhot $= m$, the velocity with which it impinges $= V$ and $n =$ the object impinged on ; the whole effect of the ſhot on this

this work, is a ſlight tremulous motion in the point of impact, incapable of producing the leaſt ſeparation of the parts: ſo much does its maſs exceed the maſs of the ſhot. There is in this caſe no method of making a breach but by mining, however tedious or difficult the operation may be.

181. There are three ways in which works that yield to cannon balls (180) may be deſtroyed:

1. By ſeparating the conſtituent parts, when the ſhot cannot penetrate.

2. By penetrating without ſplitting or ſhivering them.

3. Or by producing both theſe effects at the ſame time.

In the firſt caſe, the upper parts being by repetition of the ſhocks deprived of their baſe fall down; as in walls built very ſolidly of hard ſtones, cemented with mortar: the more ſpeedily to effect this, ſhot of the largeſt calibre ſhould be projected with the greateſt initial velocity, and the guns placed very near to the object, and fired in *falvos*; that the ſeveral ſhocks being made at the ſame inſtant, may be the more efficacious. The 64lb. ſhot formerly in uſe, were well adapted to this purpoſe; as they demoliſhed the wall in a very little time, even with an initial velocity leſs by $1\frac{1}{2}$ than that of a 32lb. ſhot; ſince from the greater quantity of movement, they ſooner ſeparate and open works of maſonry (Treatiſe on Moving Bodies, 370, 371, 372). Theſe obſervations on walls conſtructed of hard ſtone and lime, are in ſome degree applicable to works cut out in ſoft or friable ſtone; with this difference that the upper part of the rock being by its nature firmly fixed in the ground, is leſs ſhaken than a wall ſupported by earth, which though an adjunct, is little affected by the ſhock; whereas, the rock being one body, the ſhock is communicated to its whole maſs; and is ſo generally diffuſed, as to be almoſt inſenſible. Suppoſing the two works to be of equal tenacity, that cut out of the rock will ſuffer leſs from the ſhot.

182. Works are deſtroyed in the ſecond manner (181, No. 2) when the ſhot penetrating to different depths, diſunite the contiguous parts; as in turf, earth, &c. The formula $fS = Dn^2$ (246), ſerves to determine preciſely the penetrations of ſhots of different diameters, into works of this kind: the penetration of a 32lb. ſhot, which with an initial velocity of 1517 feet, impinges on a work of this ſort, is to that of a 4lb. ſhot, with the velocity of 1010 feet, as $5.760 \times 1517^2$:

$\times 1517^2 : 2.\ 881 \times 1010^2$ (161). If a 32lb. ſhot (146) with an initial velocity of 1517 feet, penetrate a butt of earth to the depth of 20 feet, a 4lb. ſhot with the velocity of 1010 feet, will under the ſame circumſtances, penetrate only to the depth of $4\frac{1}{2}$ feet; therefore, intrenchments 5 feet thick cannot be pierced by 4lb. ſhot that impinge with this velocity. The ſame formula will determine the diameter or velocity that ſhot ought to have to penetrate a parapet of a given conſiſtence and thickneſs (146): if the thickneſs $= S$ be 8.43 feet, and the conſiſtence $= F$ be 37046, by ſubſtituting theſe data in the formula, we ſhall find that ſhot which have a velocity of 1012 feet, to paſs through this parapet, ought to be 3. 653 inches in diameter, which correſponds to an 8lb. ſhot (161).

183. To determine the relative penetration of ſhot of different diameters, fired at different diſtances againſt a penetrable and homogeneous butt, the remaining velocity $= V$ with which the ſhot from the diſtance $= q$ with an initial velocity $= c$ impinges, muſt be found from the movement of impulſion: for this purpoſe the formula $q = \frac{c\,r\,t}{r+t}$, (161) will give the time $= t$; and, the value of $r$ being given, the time may be ſubſtituted in the formula $V = \frac{c\,r^2}{r+t}$, (162).

Having thus found the value of V, the compound velocity with which the ſhot impinges, may be conſidered as equal to the remaining velocity (179) without any material error; on this principle, the following table of the relative penetrations of ſhot of different diameters, impelled from guns loaded with the largeſt and the medium charges, againſt a penetrable and homogeneous butt, from four different diſtances has been calculated; the initial velocities are as before expreſſed (150) and from the reſiſtance of the air, in a 32lb. ſhot $r = 12$. By firing one round, the abſolute penetration of a ſhot into a given butt will be determined; and, from the relative penetration it will be eaſy to aſcertain the abſolute penetration of other ſhot, under the ſame circumſtances into the ſame butt. For example, if a 32lb. ſhot with the largeſt charge, fired cloſe to the butt, penetrate to the depth of 22 feet, an 8lb. ſhot fired with the largeſt charge, at the diſtance of 1000 yards, will penetrate only

to

to the depth of 6 feet If a 16lb. ſhot with the medium charge, fired at the diſtance of 340 yards, penetrate 10 feet, a 4lb ſhot with the medium charge, at the diſtance of 680 yards, will penetrate only to the depth of $3\frac{1}{7}$ feet.

The relative penetrations of ſhot, projected from different diſtances, with given initial velocities.

| Nature of Guns. | Weight of Powder. lbs. | Weight of Powder. oz. | Diameter of Shot. Inches. | Value of $r$ | Initial Velocities. Feet. | Relative Penetrations. Cloſe to the Butt. | At 340 yards. | At 680 yards. | At 1000 yards. |
|---|---|---|---|---|---|---|---|---|---|
| 32 | 13 | 2 | 5.760 | 12 | 1517 | 33210 | 26355 | 20726 | 16015 |
| 16 | 6. | 9 | 4.566 | 9.5 | 1618 | 29952 | 22877 | 17082 | 12452 |
| 8 | 4 | $14\frac{3}{4}$ | 3.653 | 7.6 | 1696 | 26000 | 18696 | 13069 | 8837 |
| 4 | 2. | $7\frac{1}{2}$ | 2.881 | 6 | 1720 | 21128 | 14122 | 8902 | 5290 |
| 32 | 9. | $13\frac{1}{2}$ | — | — | 1350 | 26240 | 20262 | 15356 | 11430 |
| 16 | 4 | $14\frac{1}{2}$ | — | — | 1416 | 22932 | 16754 | 11935 | 8255 |
| 8 | 3. | $4\frac{1}{2}$ | — | — | 1450 | 19229 | 13106 | 8566 | 5311 |
| 4 | 1 | $10\frac{1}{4}$ | — | — | 1467 | 15516 | 9563 | 5458 | 2867 |

184. To judge of the total effects of ſhot, it ſhould be obſerved; that the larger the ſhot are, the ſooner the upper parts are deprived of their baſe, and fall down. If $D u^2$ expreſſing the penetration of ſhot, be multiplied by $D^2$ a quantity proportional to the baſe of the cylindrical cavity, made by the ſhot, $D^3 U^2$ will be expreſſed by the ſize of the hole; that is to ſay, the holes made by the ſhot are in the compound ratio of the weight of the ſhot, and the ſquare of its velocity. The effects of a 64lb. ſhot impinging on a parapet of earth, with a velocity of 1247 feet, are to the effects of a 32lb. ſhot, with an initial velocity of 1350 feet, as $64 \times 1247^2 : 32 \times 1350^2$ or as 43 : 25 nearly.

Hence it appears, that 64 prs. are in both caſes (181) more proper for battering in breach than 32 prs. and the ſole reaſon why they are not uſed in the attack of places, is the difficulty of tranſporting and working them.

185. Since

185. Since ſolid and reſiſting bodies are demoliſhed by the diviſion of their parts, and thoſe that are leſs tenacious by the penetration of ſhot into them (182, 183); bodies partaking of theſe two phyſical qualities, are demoliſhed in a compound manner (181, No. 3): of this kind are walls built of brick or ſimilar materials. The effects of ſhot on walls are much modified by the proportion that the force of percuſſion bears to the reſiſtance. When two ſhot of different diameters penetrate to great depths, the holes are in the ratio of $D^3 u^2$ (184): but, if one penetrate to a great depth, and the other but a little way, this proportion will not be juſt; for, the hole made by the latter, is leſs than what reſults from the expreſſion $D^3 u^2$; ſo that if its force be only ſufficient to overcome the reſiſtance, it will bury but a ſmall part of its circumference. Hence it is eaſy to comprehend, why ſhot projected from 8 and 4 prs. are ſometimes inſufficient to beat down walls of this kind; while that they produce all the effects expected from them, when fired againſt other walls. The direction of the ſhock, conſidered relatively to the thickneſs of the wall, likewiſe contributes to modify its effects: a ſhot that with great impetus impinges with a direct ſhock on a thin wall, paſſes through, and only makes a hole, without ſhaking or diſuniting the contiguous parts: but, if a wall of the ſame quality be thick enough to receive all the force of the ſhot, it, beſide making a hole, ſhakes and looſens the reſt of the wall. A ſingle wall is ſooneſt demoliſhed by firing againſt it directly with ſmall charges, or obliquely with large ones; ſince the ſhot not being able to paſs through, it receives all its force: the ſervice of artillery in richochet and hot-firing, is diſcuſſed in the ſubſequent treatiſe.

## CHAP. IV.

### Of the Effects of Cannon Shot in Engagements.

186. In forming a train of artillery for the ſervice of an army in the field, there are ſeveral points to be conſidered: the nature and diſpoſition of the ground; the kind of war that is to be carried on; the intended plan of ope-

rations; the number and quality of the troops that compoſe the army, and their manner of fighting.

A general commanding an army, ſhould be acquainted with the effects of artillery, that he may know when it can be employed to advantage; and how far, when judiciouſly and ſkilfully ſerved, it can contribute to the attainment of his object (141, 142).

187. In countries where the tranſport of carriages is attended with no great difficulty, the train of artillery that march with armies, are compoſed of medium guns, caſt of metal containing $\frac{1}{8}$ of tin, and carrying balls of 16, 8, and 4lbs (64). Theſe guns are divided into brigades: the heavieſt ſhould not weigh more than 32 cwt. as the bridges conſtructed by the peaſants for their carts and waggons can ſeldom ſupport a greater weight: beſide, if the road be not hard, or have been ſpoiled by preceding rains, it will be impoſſible to move heavier guns, even at the opening of the campaign; and, in autumn, when the roads are generally deep, the cattle will be exhauſted with the fatigues they have already undergone. Therefore, *the ſpecies of artillery ſhould be always adapted to the nature of the country.*

In carrying on offenſive operations in a champaign country, the train of artillery ſhould be compoſed of 8 prs.; to which may be added a few 16 prs. for occaſions of great exertion: there ſhould be a few ſhort light guns (97) to accompany any corps of the army that may be deſtined by rapid marches to fall on the enemy's convoys or cut off their detachments. In deep hilly countries, ſhort 8 and 4 prs. ſhould be the heavieſt guns uſed: indeed, an exact knowledge of the nature of the country is the beſt rule for determining the calibre as well as number of the guns.

When the army is to remain on the defenſive in a country where the roads are tolerably level and good, and there is no great probability of being obliged to make very long movements, the number of 16 prs. ſhould be greater than would follow an army acting offenſively in the ſame country; but if this defenſive ſyſtem be carried on in a ſtrong country, where the tranſport of carriages is difficult, and long and rapid marches may be indiſpenſibly neceſſary; the brigades of artillery ſhould be ſo conſtituted as eaſily to keep up with the army. Any poſt that the general may wiſh to occupy and maintain during the campaign ſhould be provided with guns of large calibre (71).

Having

Having already treated of the nature and importance of theſe poſts in the 6th Book of Military Architecture, I leave it to the profeſſors of the academies to explain them fully to the cadets of the royal corps of artillery; that being equally maſters of the principles of tactics and fortification, as of their own profeſſion, the ſervice may on every emergency reap the greateſt benefit from their knowledge and exertion.

188. Theſe guns are able to bear the largeſt charges; yet they ſhould not be uſed but in caſes of abſolute neceſſity and when they cannot derange the firing: in all other caſes, the charges ought to be proportioned to the initial velocity that the projectile ſhould have to produce the deſired effect. For example, the medium charge may be uſed in enfilading columns of troops; as the ſhot from its greater velocity will deſtroy a greater number of men: but if the leſs charge will impel the ſhot from front to rear of the column, the medium charge would ſerve no other purpoſe than unneceſſarily to heat the gun. Againſt an enemy drawn up three or four deep, the leſs charges ſhould be uſed; as the leaſt charges may from ſome neglect in wadding be uncertain in their execution.

189. From the deſire of firing quick in action the greater part of the ſhot do not take effect; ſince in working the guns with ſuch precipitation, there will moſt probably be a want of attention in loading, laying, or ſome other eſſential point. The frequency of firing ſhould be regulated by the certainty of doing execution; thoſe who are actuated by any other motive fruſtrate the deſigns of the general, and are the cauſe of all the bad conſequences that may enſue: they can neither be juſtified by the anxious deſire that the troops expreſs to ſee them fire quickly, nor by a chimerical point of honour, which is by ſome individuals abſurdly placed in firing ſo many rounds in a minute. Whenever the diſtance is ſo great or the object ſo ſmall, that the chance of hitting it is very uncertain and precarious, it would be much better to ceaſe firing and wait till by a nearer approach or by ſome movement of the enemy, an opportunity offers of doing effectual execution.

190. In engagements, the enemies troops are the objects againſt which cannon ſhot are directed; it is therefore highly neceſſary to know the effects that ſhot of different diameters, and with different velocities, can produce upon a body of troops, according to the diſtances at which they engage;

otherwiſe, the artilleriſt will in a variety of circumſtances be unable to uſe his gun to the greateſt advantage (141).

In firing at infantry, the height above the plane of the ground is about 6 feet, and in firing at cavalry not more than 10 feet; wherefore the diſtance ſhould never exceed 680 yards, except when the enemy is drawn up ſo deep, that the ſhot can hardly fail of taking effect.

The execution of cannon ſhot in action is eſtimated from the number of men that are killed, or wounded in ſuch a manner as to be diſabled from further immediate ſervice: it is unneceſſary to conſider the depth of the wounds; as a man ſtruck by a cannon ball is generally incapacitated, at leaſt for the preſent. The great object of the artilleriſt "*is* "*to endeavour to ſtrike with each ſhot the greateſt number of* "*men poſſible*" (141 142): this depends;

1. On the diſpoſition of the enemy, and the nature of the ground.

2. On the calibre of the guns and the judicious uſe of round or caſe ſhot:

3. On the velocity with which the ſhot are impelled, and the diſtance between the battery and the enemy.

191. There are two caſes with regard to the nature of the ground (190 No. 1); the firſt, when the two armies are drawn up on ground nearly on the ſame plane: the ſecond, when they are on planes differently inclined. When they are both on the ſame plane, whether horizontal or inclined, the ſurface expoſed to the fire of the cannon is a part of the firſt line; ſhould this be the head of a column, or the flank of a body of troops ranged in order of battle, the ſhot by enfilading them will be very deſtructive. But if the enemy be drawn up three or four deep in front of the gun and within proper diſtance, caſe ſhot will do moſt execution; ſince a round ſhot can in this caſe, only carry off a file of three or four men, whatever be its diameter or velocity.

192. When the two armies are on different planes, the execution of the artillery muſt depend on the extent of front and depth of files: on conſidering the principal caſes that can occur in the two general diſpoſitions of an army, viz. drawn up in column, or line; it will appear:

1. That if the enemy be drawn up in column on the ſlope G F inclined towards F, the head only of the column G (Pl. 6. Fig. 21.) will be expoſed to the can-

non

non A: caſe ſhot will then be preferable to round ſhot, if the diſtance A G admit of it.

2. If the column be on the ſlope G E inclined towards E or on the height N B M; it will preſent to the cannon A an object of great extent, and be from its ſituation very much expoſed: the cloſer the ranks are, and the deeper the column, the more deſtructive will be the fire of the artillery.

3. If A B be within range of caſe ſhot, its greateſt effect will be at N B M, where from the divergence of the ſhot each may ſtrike a man; while that in G E much nearer to the gun, the ſhot not having had time to ſpread, each man will be ſtruck by two or three, and the execution will of courſe be leſs.

4. When the column reaches the horizontal plain P E, it will ſuffer leſs than in the former ſituation: if A and P E be nearly in the ſame plane, fewer men will be expoſed than at A P: the caſe ſhot ſhould then be compoſed of balls of the largeſt diameter that each of them may kill or wound more than one man; and then every ball that ſtrikes will enfilade the whole diſpoſition. If P E be lower than A, ſo that the guns at A muſt be much depreſſed; caſe ſhot compoſed of the ſmalleſt balls will be the beſt; ſince from the greater number their effect will be equal to that produced in the former inſtance by the large balls; there being in this caſe no probability of eſtabliſhing an enfilade.

5. The enemies army drawn up three or four deep upon the height G will be expoſed to the ſame danger, as when in column on the ſlope G F; but by retiring a little, G will ſerve as a parapet, under the cover of which they may ſecurely fire at A.

6. Should the enemy be drawn up three or four deep upon the ſlope E G, the greateſt effect of a round ſhot will be to carry off a file of men even when the ranks are very cloſe: but if there be a conſiderable interval between them, caſe ſhot, when the diſtance admits of it, will be moſt deſtructive, both in this inſtance and when the enemy has advanced to the horizontal plain P E.

193. The direction in which guns ſhould be fired depends on the initial velocity of the ſhot, its diameter, and the di-

ſtance from the enemy; the formulas $q=\frac{crt}{r+t}$, $S=\frac{32.18t^2}{2}$ (165, 166) will give a ſolution of the problem.

The opinion of ſome artilleriſts, that guns in time of action ought always to be fired horizontally, or at moſt with $\frac{1}{4}$ degree of elevation, can only be juſt in particular caſes; the following example will evince the neceſſity of ſometimes deviating from this maxim. Let the gun AB (Pl. 5. Fig. 14.) be fired in the horizontal direction AC with the charge that gives an initial velocity of 1416 feet; and from the reſiſtance of the air, $r=9.5$. Now ſuppoſing the gun and the enemy to be in the ſame horizontal plane; Let KG repreſent the vertical diſtance between the two planes AC, DF; KG will then expreſs the ſpace $=S$ paſſed through by the power of gravity, and by ſubſtituting the value of KG in the formula $S=\frac{32.18t^2}{2}$ it will give the time of the ſhot's flight before it touch the ground in the plane DF: then by ſubſtituting in the formula $q=\frac{crt}{r+t}$ the known value of $t$, the extent of the range $AK=DG=q$ will be found. For example, if $KG=5\frac{1}{4}$ feet, the time$=t$ will be 56 parts of a ſecond; and by ſubſtituting the values of $c, r, t$ in the formula, $q=760$ feet. To ſtrike the ground then in the ſame plane DF at a greater diſtance, the gun muſt be elevated in proportion to the increaſe of diſtance; ſhould the enemy be at G where the ſhot touches the ground at the firſt graze it will only ſtrike his feet; to hit him in the breaſt the gun muſt be elevated.

194. The more clearly to explain this theory, and enable others to apply it to the practice on ſeveral occaſions that occur on ſervice, the following table has been calculated: the gun and butt are ſuppoſed to be in the ſame plane, and from the reſiſtance of the air $r=12$ in a 32lb. ſhot; the wads are rammed with equal force and in the manner before expreſſed, (143, 150); except in the quick firing, when none are uſed.

Angles

## Angles of Elevation for firing Guns of different Lengths and Calibres with different Charges of Powder, to project Shot to different Distances.

| Nature of Guns. | | Weight of Powder. | | Initial Velocity. | Distant from the Butt. 340 Yards. | | | | 680 Yards. | | | | 1000 Yards. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Line of descent. | | Elevation. | | Line of Descent. | | Elevation. | | Line of Descent. | | Elevation. | |
| | Pr. | lbs. | oz. | | Feet. | In. | Deg. | Min. | Feet. | In. | Deg. | Min. | Feet. | In. | Deg. | Min. |
| Of the common length. | 32 | 9 | 13¼ | 1350 | 10 | 6 | — | 35 | 48 | 1 | 1 | 21 | 120 | — | 2 | 17 |
| | 16 | 4 | 14¼ | 1416 | 9 | 9 | — | 32 | 46 | 4 | 1 | 18 | 120 | — | 2 | 17 |
| | 8 | 3 | 4¼ | 1450 | 9 | 8 | — | 32 | 48 | — | 1 | 21 | 130 | — | 2 | 29 |
| | 4 | 1 | 10¼ | 1467 | 10 | — | — | 33 | 52 | 9 | 1 | 28 | 160 | — | 3 | — |
| | 16 | 3 | 10¼ | 1240 | 13 | — | — | 44 | 63 | 7 | 1 | 47 | 169 | 6 | 3 | 14 |
| | 8 | 2 | 7¼ | 1265 | 13 | — | — | 44 | 67 | 4 | 1 | 53 | 191 | — | 3 | 38 |
| | 4 | 1 | 3¼ | 1283 | 13 | 6 | — | 45 | 75 | — | 2 | 6 | 236 | — | 4 | 30 |
| Short guns (66.) | 8 | 2 | 7¼ | 1206 | 14 | 6 | — | 49 | 76 | — | 2 | 8 | 220 | — | 4 | 11 |
| | 4 | 1 | 3¼ | 1222 | 15 | — | — | 50 | 86 | 10 | 2 | 26 | 278 | — | 5 | 17 |
| | 8 | 1 | 10¼ | 978 | 23 | 6 | 1 | 19 | 133 | — | 3 | 44 | 425 | — | 8 | 6 |
| | 4 | — | 13¼ | 978 | 25 | 7 | 1 | 26 | 164 | 6 | 4 | 36 | 633 | — | 11 | 55 |
| | 8 without wads. | 1 | 10¼ | 675 | 57 | 3 | 3 | 12 | 405 | — | 11 | 13 | 1843 | — | 31 | 34 |
| | 4 without wads. | — | 13¼ | 675 | 65 | 7 | 3 | 41 | 596 | — | 16 | 18 | — | — | — | — |

195. Many practical inferences may be deduced from this table:

1. Guns of the common length loaded with the medium charge ſhould be elevated half a degree above the horizon to range 340 yards, and 1° 20′ to range 680 yards; the elevation muſt be greatly increaſed to range 1000 yards. The leſs the calibre of the gun is, the higher muſt be the elevation.

2. The elevation of ſhort guns fired with the leſs charges muſt be greater than of guns of the common length to range the ſame diſtance.

3. If a ſhort 4 pr. loaded with the leſs charge, range 1000 yards, the line of deſcent is 278 feet; wherefore the ſhot's path being a curve of the fourth kind, it will do much leſs execution in enfilading troops, than ſhot fired from guns of the common length whoſe path is a curve of the ſecond kind.

4. The elevation of ſhort guns loaded with the leaſt charge increaſe in the ratio of the diſtance: thus the curve deſcribed by ſhot fired from 8 and 4 prs. to the diſtance of 1000 yards is of the fourth kind; from the angle of incidence they can be of no ſervice in enfilading, and are very uncertain: the angle of incidence (168) at the diſtance of 1000 yards being much larger than the angle of elevation, if the ſhot fall on ſoft ground they bury themſelves at the firſt graze.

5. Shot fired from ſhort guns with the leaſt charges and without wads, which range only 680 yards, alſo deſcribe a curve of the fourth kind; they are conſequently uſeleſs in enfilading, and their execution is uncertain.

6. If to theſe reflections be added the conſideration, that in pointing ſhort guns the eye is more eaſily deceived, from the proximity of the two points of ſight, than in longer guns; and that in the latter the angle of elevation being leſs, the angle of incidence is leſs alſo; ſo that the ſhot on touching the ground riſe and from their richochet are very dangerous: it will be evident that to derive from the uſe of artillery the greateſt poſſible advantages, *long guns ſhould ever be preferred to ſhort ones of the ſame calibre.* The good effects reſulting from this will be more fully diſplayed in the ſequel.

196. To

196. To form a compariſon of the effects that ſhot of different diameters with different initial velocities produce at different diſtances on a body of troops; they muſt be conſidered as a homogenous butt: then the formula $S=Du^2$ (183) will give the relative penetrations. The abſolute number of men that a ſhot with a given initial velocity will paſs through may be determined by experiment.

The relative penetrations in the following table have been calculated on a ſuppoſition that from the reſiſtance of the air $r=12$ in a 32lb. ſhot, in order to compare together the number in this and the preceding table (183). The calculations are not carried beyond 680 yards, which is conſidered in field engagements as the greateſt diſtance that ſhot can range to, with a certainty of doing execution; in extraordinary caſes indeed, when the nature of the ground and the poſition of the enemy are very favourable (192), the range may be extended with tolerable ſucceſs.

The relative Penetrations of Shot projected from different Diſtances with given initial Velocities.

| Nature of Guns. | Prs. | Weight of Powder. lbs. | oz. | Initial Velocity. Feet. | Cloſe to the Butt. | At 340 yards. | At 680 yds. |
|---|---|---|---|---|---|---|---|
| Common length. | 16 | 3 | 10¾ | 1240 | 17571 | 11878 | 8509 |
| | 8 | 2 | 7½ | 1265 | 14625 | 9360 | 5743 |
| | 4 | 1 | 3¾ | 1283 | 11840 | 6754 | 3479 |
| Short Guns. | 8 | 2 | 7½ | 1206 | 13329 | 8358 | 4919 |
| | 4 | 1 | 3¾ | 1222 | 10784 | 5933 | 2944 |
| | 8 | 1 | 10¼ | 978 | 8746 | 4874 | 2450 |
| | 4 | — | 13½ | 978 | 6896 | 3230 | 1271 |
| | 8 | without wads | 10¼ | 675 | 4110 | 1738 | 427 |
| | 4 | | 13¼ | 675 | 3241 | 1024 | 251 |

197. To reduce into numbers the relative penetrations inſcribed in the tables (183, 196), make the following or ſimilar experiment: with a charge that gives a known initial velocity, fire a gun againſt a butt, and meaſure the penetration of the ſhot: then place two horſes or other cheap animals cloſe to the ſame butt, and lay the gun ſo that the ſhot after paſſing through the moſt ſolid parts of their bodies may

may enter the butt: on meaſuring the penetration, it will be found leſs than the former; and by comparing them together, the number of horſes that a ſhot of a given diameter, with the ſame initial velocity, could paſs through, may be aſcertained. On comparing the reſiſtance of a horſe's, with that of a man's body, the number of men that the ſame ſhot would paſs through may be eaſily calculated. An 8 lb. ſhot, with an initial velocity of 1450 feet, will paſs through 20 horſes; and in this table it is preſumed on tolerably juſt grounds, that the ſame ſhot would paſs through double the number of men, even if it ſtruck the moſt ſolid parts of their bodies; the number therefore that may be ſtruck in leſs reſiſting parts of the body and diſabled muſt be greater, and may even exceed twice the number of the former. The table has been deduced from the former proportions (183, 196).

Number of Men that can be pierced by Shot projected from different Diſtances with given Initial Velocities.

| Nature of Guns. | | Weight of Powder. | | Initial Velocities. | Cloſe to the Butt. | At 340 Yards. | At 680 Yards. |
|---|---|---|---|---|---|---|---|
| | | lbs. | oz. | Feet. | No. Men. | No. Men. | No. Men. |
| Common Length. | 32 | 13 | 2 | 1517 | 70 | 55 | 44 |
| | 16 | 6 | 9 | 1618 | 63 | 48 | 36 |
| | 8 | 4 | 14¼ | 1696 | 55 | 39 | 28 |
| | 4 | 2 | 7¼ | 1720 | 45 | 30 | 19 |
| | 32 | 9 | 13½ | 1350 | 55 | 43 | 32 |
| | 16 | 4 | 14½ | 1416 | 48 | 35 | 25 |
| | 8 | 3 | 4½ | 1450 | 40 | 28 | 18 |
| | 4 | 1 | 10½ | 1467 | 33 | 20 | 12 |
| | 16 | 3 | 10½ | 1240 | 36 | 24 | 17 |
| | 8 | 2 | 7½ | 1265 | 31 | 20 | 13 |
| | 4 | 1 | 3¼ | 1283 | 25 | 14 | 8 |
| Short Guns. | 8 | 2 | 7½ | 1206 | 28 | 18 | 11 |
| | 4 | 1 | 3¼ | 1222 | 23 | 13 | 7 |
| | 8 | 1 | 10½ | 978 | 19 | 10 | 5 |
| | 4 | — | 13¼ | 978 | 15 | 7 | 3 |
| | 8 without wads. | 1 | 10½ | 675 | 9 | 3½ | 7/8 |
| | 4 without wads. | — | 13¼ | 675 | 7 | 2 | 7/12 |

198. Several

198. Several inferences of great practical utility may be drawn from this table:

1. Guns of large calibre fired at very ſhort diſtances, with the large or even the medium charges againſt a corps of troops expoſed to be enfiladed, will cauſe much more ſlaughter than 8 or 4 prs. eſpecially if ſhort with the leaſt charges.

2. The relative effects of guns of different natures increaſe in the ratio of the diſtances; and there is greater difference between the calibres of the guns and the charges of powder.

3. Guns ſhould never be fired without wads, except in particular caſes, and when the enemy is very cloſe. Thus when 4 prs. or ſhort guns compoſe a field train, it is not becauſe they are equal in their effects to longer guns of large calibre, but only becauſe heavier guns cannot be tranſported with the ſame facility. When part of an army is to remain on the defenſive in a fixed poſt, the ſame arguments will evince the propriety of giving the preference to longer guns of large calibre.

199. If the enemy troops be drawn up three or four deep, the effects of an oblique fire will be greater in proportion as the angle of incidence on their front is more acute; ſince the reſiſtance not being ſufficient to turn the ſhot, it will penetrate in the direction in which it impinges. On the contrary, the effect will be leſs, the nearer the angle of incidence approaches to a right angle; ſince it will then only deſtroy a ſingle file, whatever be its diameter or initial velocity. In this caſe, if the two armies be within reach of muſquet ſhot, the ſituation of the artillery-men will be very perilous; for eight paces at leaſt muſt be left between every two guns, to give the men room to work them; each gun is then expoſed to the fire of eight file of muſqueteers; or in other words, each artillery-man to the fire of three or four muſquets. Thus at a ſingle diſcharge, all the artillery men may be killed or wounded; while one round from each gun can only carry off a ſingle file of the enemy: when half of the artillery-men are wounded, the gun muſt ceaſe firing; but the fire of the muſquetry will be inceſſantly kept up, in proportion to the number of men that remain.

200. The fluid generated in a piece of ordnance is ſo much the more abundant and elaſtic, as the body it muſt impel towards the muzzle is heavier (Treatiſe on Powder). Whence

Whence it is eaſy to conceive; that in putting two ſhots into a gun, the velocity of each muſt neceſſarily exceed half of the velocity that one ſhot with the ſame charge would acquire; and the quantity of motion of the ſingle ſhot is leſs than the ſum of the quantities of motion of the two ſhot: but in aſcertaining the effects of the three ſhot, their force after paſſing through the men and horſes being ſuppoſed to be entirely ſpent, the equation $S = D u^2$ which expreſſes the effects of one ſhot muſt be changed; and to make up the exceſs, the initial velocity of each of the other two ſhot muſt exceed $u\sqrt{\frac{1}{2}}$; and each ſhould ſtrike a ſeparate file. The proportion between the initial velocity acquired by one ſhot fired ſingly, and that acquired by each when two ſhot are fired together with equal charges, can only be determined by experiment, as it changes whenever the charge is altered; but it may be remarked, that in practice the velocity of each of the two ſhot is leſs than $u\sqrt{\frac{1}{2}}$: wherefore the expedient of putting two ſhot into a gun can be only advantageous when the enemy is drawn up in ſuch a manner, that each ſhot has ſufficient velocity to carry off a file. For example, ſuppoſe the enemy be drawn up eighteen deep, and each of two ſhot fired together from an 8 pr. could ſtrike a ſeparate file with an initial velocity of 978 feet, each of them would deſtroy 18 men (197): under this ſuppoſition there would be 36 men deſtroyed by the two ſhot; while a ſhot of the ſame diameter, fired ſingly with an initial velocity of 1450 feet, could deſtroy only 18 men; then its remaining velocity ſufficient to deſtroy 20 more would be uſeleſs.

## CHAP. V.

### Of the Effects of Case or Grape Shot in Engagements.

201. THERE are ſeveral kinds of ſhot that come under this head: one is formed of ſmall pieces of iron of different ſhapes and ſizes put into cylinders of tin or paſteboard; the baſes of which are cloſed by two circular pieces of wood.

A ſecond

A ſecond called *caſe ſhot*, is compoſed of ſmall iron balls put into tin cylinders; or regularly diſpoſed in linen bags faſtened to a wooden bottom, in the middle of which is a ſpindle, and wound round with cord or wire; the latter preſent the appearance of a bunch of grapes, and are called *grape ſhot*. The firſt kind is generally uſed in the defence of places; and fired from the low flanks, where in ſpite of their divergence they are uſeful in ſcouring the ditches and counterſcarps: the reſiſtance of the air, from the irregularity of their figure, renders them in effect more uncertain than ſpherical ſhot; but as the objects againſt which they are fired are always very near, they have force enough to do execution. The ſecond kind is generally deſigned for field ſervice, as the balls diverge leſs, and, from their ſpherical figure encountering leſs reſiſtance in the air, range farther.

202. In the late wars, our trains of artillery were formed of medium 4 prs. (64): the caſe-ſhot for theſe guns contained 63 or 64 leaden bullets, each weighing $\frac{1}{4}$ of an ounce; the whole weighed nearly as much as a round ſhot of the ſame diameter. In order to aſcertain their effects, the officers of artillery in 1743 made the following experiments: a 4 pr. was fired againſt a target of plank 80 feet in length by 10 in height, erected on the ſame horizontal plane with the gun; ſo that ſome of the balls after grazing roſe and ſtruck the target: caſe and grape ſhot were fired, but no difference in their effects was perceptible. In the firſt experiments, the charge was 1 lb. 10 oz. of powder, and over the wad, which was well rammed, was placed the caſe: at the diſtance of 200 yards, only 3 or 4 balls ſtruck the target. The gun being moved 30 yards nearer, 9 or 10 balls ſtruck it; but the greater part did not go through the planks, which were an inch thick: thoſe that ſtruck were partly melted, and two or three were found in different places ſticking together. At the ſecond experiment, the caſe was placed immediately over the powder and a wad rammed over the whole: at the diſtance of 170 yards very few of the balls went through the planks, though the report of the exploſion was as loud as at the former experiment; others had not force enough to enter, and thoſe that ſtruck were much more liquefied than before; 4 or 5, and at one time 15 were found ſticking ſo cloſely together as to form a lump of lead. At other experiments, when the caſe was placed over the

the powder without a wad, the balls at 170 yards ſtruck the target with rather more force, and were not liquefied, though the report at the diſcharge was more feeble than at the ſecond experiment. At each round, the number of balls that ſtruck the target was between $\frac{1}{3}$ and $\frac{1}{6}$ of the whole; and $\frac{1}{2}$ or $\frac{2}{3}$ of theſe ſtruck it below a horizontal line drawn 5 feet from the ground. The greateſt divergence of the balls at this diſtance was 60 feet, but frequently not more than 33.

203. Some rounds being fired from the ſame gun at 170 yards, with $1\frac{1}{4}$ lb. of powder; the number of balls that ſtruck the target was between $\frac{1}{3}$ and $\frac{1}{6}$ of the whole, but their force was leſs: in theſe, as in the former experiments, a wad was rammed over the powder; in the ſecond, a wad over the whole; and in the third no wad was uſed. Two caſes being put into a gun and fired together, the number of balls that ſtruck the target was between $\frac{1}{3}$ and $\frac{1}{9}$ of the whole number in the two caſes; many of thoſe that touched the target had not force enough to penetrate. The gun being removed to 200 yards and fired again with two caſes, about $\frac{1}{20}$ of the balls ſtruck the target, but with much leſs force.

204. It reſults from theſe experiments (202, 203):

1. That caſe-ſhot of this nature ſhould never be fired at a greater diſtance than 200 yards, againſt objects not exceeding 10 feet in height.

2. A wad ſhould be put between the powder and caſe; but as ſometimes in quick firings this muſt be diſpenſed with, the balls will yet have force enough at 200 yards to wound a man.

3. That the greateſt poſſible effect of caſe ſhot is when fired againſt an enemy drawn up in form of a vaſt amphitheatre between 170 and 200 yards diſtant, by putting two caſes into the piece and uſing the leſs charges of powder.

4. That with one caſe, 6 or 7 men of the front rank may be ſtruck at 170 yards; and ſtill a greater number when two caſes are put into the gun: when advanced nearer to the enemy, the balls will paſs through the bodies of the men in the front rank and wound thoſe in the rear.

5. That the firing with caſe ſhot ſhould commence at 170 yards in order to acquire a ſuperiority over the enemy's muſquetry; the effect of platoon firing at that diſtance

diſtance is uncertain, while caſe ſhot fired with judgement will ſtrike at each round a certain number of men.

At other experiments (202, 203) with caſe ſhot compoſed of iron balls 1 oz. in weight, the whole caſe weighing as much as the round ſhot of the ſame diameter; it reſulted that at 200 yards, 3 or 4 balls ſtruck the target, and at 170 yards 8 or 10 ſtruck it; the force of theſe balls ſeem to exceed that of the leaden bullets.

205. Theſe concluſions agree with what has been advanced on the ſame ſubject, in the practice of artillery and the elements of tactics. It will be ſhewn in the ſequel, that greater advantages may be derived from the uſe of field pieces than has been hitherto done, in conſtantly maintaining a decided ſuperiority of fire over infantry drawn up in front of the guns (199) through the uſe of tin cylinders filled with iron balls weighing more than 1 oz.

To aſcertain this, the force and direction with which each ball is impelled, and the proper elevation for the piece ſhould be conſidered: the two following tables will give a juſt idea of their force; in the firſt are ſet down the relative penetrations calculated (183) on a ſuppoſition that the initial velocity is 1450 feet, and that from the reſiſtance of the air to a 32 lb. ſhot $r=12$, in order to form a compariſon between theſe and the former tables (183, 196): in the ſecond are marked the reſults of the former experiments (197) and the penetrations inſcribed in the firſt table are reduced to abſolute numbers.

TABLE

Relative penetrations of iron caſe ſhot.

TABLE I.

| Weight of ball. oz. | Value of $r$ | Cloſe to the butt. | At 170 yards. | At 340 yards. | At 510 yards. | At 680 yards. |
|---|---|---|---|---|---|---|
| 13 | 3.8 | 9614 | 6553 | 4283 | 2655 | 1538 |
| $6\frac{1}{2}$ | 3. | 7580 | 4642 | 2645 | 1365 | 620 |
| $3\frac{1}{4}$ | 2.39 | 6040 | 3251 | 1524 | 604 | 181 |
| 1 | 1.65 | 4139 | 1621 | 470 | 74 | 2 |

TABLE II.

Number of men that can be pierced in the moſt ſolid parts of the body by caſe ſhot, of the following weight projected from different diſtances, with an initial velocity of 1450 feet.

| Weight of balls. oz. | Cloſe to the butt. Men. | At 170 yards. Men. | At 340 yards. Men. | At 510 yards. Men. | At 680 yards. Men. |
|---|---|---|---|---|---|
| 13 | 20 | 14 | 9 | 6 | 4 |
| $6\frac{1}{2}$ | 16 | 10 | 6 | $3\frac{1}{2}$ | 1 |
| $3\frac{1}{4}$ | 13 | 7 | $3\frac{1}{2}$ | $1\frac{1}{2}$ | $\frac{1}{195}$ |
| 1 | 9 | 4 | $\frac{5}{7}$ | $\frac{1}{7}$ | $\frac{1}{9614}$ |

206. From theſe premiſes (190, 191, 192) it may be inferred.

1. That when balls of which caſe ſhot are compoſed weigh 13 oz. each, every ball can pierce a file of 20 men, when fired very cloſe; and 4 men at the diſtance of 680 yards. If each ball weigh $6\frac{1}{2}$ oz. it can pierce 16 men when very near; 10 at 170 yards; 3 or 4 at 510 yards; and one only at 680 yards. If each ball weigh 1 oz. it can pierce 4 men at 170 yards; and mortally wound 1 man at 340 yards; the latter is expreſſed by

by the fraction $\frac{5}{6}$; the ſame ball at the diſtance of 680 yards will hardly make a contuſion, which is expreſſed by the fraction $\frac{1}{9\,6\,1\,4}$.

2. Balls of 1 oz. at 170 yards, thoſe of $3\frac{1}{4}$ oz. at 340 yards, thoſe of $6\frac{1}{2}$ oz. at 510 yards, and thoſe of 13 oz. at 680 yards, produce the ſame effect; viz. of deſtroying 4 men; which evinces the propriety of uſing cylinders filled with large balls for great diſtances, and with the ſmaller balls for ſhort diſtances.

3. On comparing the numbers in the two tables (197, 205), we find that an 8 lb. ſhot, with an initial velocity of 1450 feet, will paſs through a file of 40 men when fired very cloſe to them; 28 at the diſtance of 340 yards, and 18 at the diſtance of 680 yards: while a $6\frac{1}{2}$ oz. ball will only deſtroy 16 men when very near, 6 at the diſtance of 340 yards, and 1 man at 680 yards; ſo that with caſe-ſhot of this nature, if 5 balls ſtrike 5 ſeparate files, the effects when very near will be $16 \times 5 = 80$ men deſtroyed, $6 \times 5 = 30$ men at 340 yards, and 5 only at 680 yards. Hence it reſults, that the effects of caſe ſhot fired under ſimilar circumſtances, are greater than of round ſhot of equal diameter, when the diſtance does not exceed 340 yards; but at 680 yards round ſhot have a decided advantage.

207. Theſe remarks (205, 206) are applicable to every caſe that can occur, allowance being made for the difference of the initial velocities; wherefore the effect of the initial velocity on caſe ſhot impelled with a given charge of powder ſhould be aſcertained. It has been found experimentally, that when the balls are regularly arranged in the tin cylinder in the manner that will be hereafter pointed out, and are equal in weight and diameter to the correſponding round ſhot, the greater part of them are impelled with the ſame initial velocity as the round ſhot, but the remainder with leſs; provided the charges be equal. This reſult is conſtant; hence the effects of caſe ſhot fired from different diſtances with different charges of powder may be determined with ſufficient accuracy for practice (205).

208. In firing caſe ſhot, the balls are obſerved at firſt to take a diverging direction, and for a certain diſtance to form a kind of a cone; the baſe of which is towards the object fired at, and the vertex towards the gun.

It is impoſſible from theory alone to determine the di-

rection that each ball takes after the caſe is broken; ſince the contact of the balls and their reciprocal preſſures at the diſcharge and at the commencement of their divergence are unknown: It muſt then as far as poſſible be aſcertained experimentally.

Experiments made with the greateſt attention have given the following reſults;

1. The conical figure is preſerved for a certain diſtance; after which it is entirely loſt.

2. The proportion between the formation of the cone and the point where it begins to loſe the regularity of its figure depends on the ſize of the balls, and their initial velocity: the diſtance will be leſs in proportion as the balls are ſmaller, or their initial velocity leſs.

3. At equal diſtances, balls impelled from guns of the common length diverge much leſs than balls of the ſame weight and diameter impelled from ſhorter guns with the ſame charge. This muſt be a familiar remark to ſportſmen who have uſed fowling pieces of different lengths.

4. When the balls are ranged in the cylinder in regular order, they diverge much leſs than when put in careleſsly; thoſe of 13, $6\frac{1}{2}$ and $3\frac{1}{4}$ oz. may be regularly diſpoſed in tin caſes of the diameter of 16, 8, and 4 prs.; and ſuch only will be in future conſidered: 1 oz. balls ſhould be diſpoſed in the cylinder in the moſt convenient manner, and fired at any diſtance leſs than 220 yards.

5. From certain diſtances a greater number of men may be ſtruck by caſe than by round ſhot, if the gun be properly laid.

209. The angle that the axis of the gun ſhould form with the horizon is determined (165, 166) on a ſuppoſition that the balls in the tin caſe are impelled in the direction of the axis, which is not always juſt; as they ſometimes quit the caſe under different angles. The leaſt error in loading or pointing a gun may render a round ſhot of no effect, but be of little conſequence in firing with caſe ſhot.

210. In order to ſhew in one part of view the moſt intereſting particulars in the uſe of caſe ſhot, the following table has been calculated; the initial velocities of a 32 lb. ſhot are ſuppoſed to be 1450 and 1206 feet, and $r = 12$ for the reſiſtance of the air, to enable the reader to compare it with the former tables.

Angles

Angles of Elevation at which Guns ſhould be fired with Caſe Shot, with the Initial Velocities of 1450 and 1206 feet, from the following Diſtances, ſuppoſing the Battery and the Enemy to be in the ſame Plane.

| Nature of cafe fhot. | Initial velocity. | Diſtances between the battery and enemy. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1760 yards. | | | 1440 yards. | | | 960 yards. | | | 680 yards. | | |
| | | Time of defcent. | | Elevation. | Time of defcent. | | Elevation. | Time of defcent. | | Elevation. | Time of defcent. | | Elevation. |
| | | M. | S. | Deg. Min. | M. | S. | Deg. Min. | M. | S. | Deg. Min. | M. | S. | Deg. Min. |
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211. From this compariſon the following practical inferences may be drawn;

1. Balls of $3\frac{1}{4}$ oz. that with an initial velocitiy of 1450 feet range 680 yards, deſcribe a curve of the ſecond kind; the remaining force at that diſtance may be expreſſed by the fraction $\frac{1}{192}$; but it is injudicious to fire caſe ſhot of this nature at ſuch a diſtance, as their execution is trifling: 1 oz. balls ought never to range 680 yards, as they deſcribe a curve of the fourth kind, and are totally uſeleſs in enfilading; their remaining force may be expreſſed by the fraction $\frac{1}{960}$, and is hardly ſenſible.

2 Balls of $3\frac{1}{4}$ oz. that with an initial velocity of 1450 feet range 510 yards, deſcribe a curve of the ſecond kind, and may be of ſervice in enfilading; but as they can deſtroy only one or two men, this is the greateſt diſtance at which they ſhould be fired: as to 1 oz. balls, though at 510 yards their curve is of the ſecond kind, yet as the expreſſion of their force is $\frac{1}{7}$, the diſtance is too great: 340 yards ſhould be their longeſt range, the expreſſion of each ball is then $\frac{5}{6}$.

3. As a ball of $6\frac{1}{4}$ oz. with an initial velocity of 1450 feet can only deſtroy one man at 680 yards, it ſhould be conſidered as the greateſt diſtance; though from the nature of the curve, it might ſtill be uſeful in enfilading.

A ball of 13 oz. with the ſame velocity and at the ſame diſtance will deſtroy a file of 3 or 4 men.

4. When the initial velocity is 1206 feet, the curvature of the lines of deſcent is greater than when it is 1450 feet; conſequently caſe ſhot with the former velocity are leſs proper for enfilading: they ſhould only be uſed at ſhort diſtances, in proportion to the difference between the actual velocity and 1450 feet.

5. A ſmall charge of powder can only have the ſame effects as a large one, when the enemy is drawn up 3 or 4 deep, and ſo cloſe that a ſingle ball can carry off a whole file; the ſame obſervation holds good with reſpect to ſhort guns, ſince from the initial velocity (151) their range is ſhort.

6. The number of balls that, with velocities equal to or leſs than thoſe above mentioned, will ſtrike an object of certain dimenſions at a given diſtance, can only

only be determined by experiment; [illegible] sible to ascertain the particular direction of each [illegible]

212. The results of the preceding theory [illegible] whether the resistance of the air be considered as [illegible] or of any other determinate value, will never exactly [illegible] with practice; since the absolute effects of case shot cannot be assigned, but only a proportion established between the greatest and least effects: [illegible] to the case shot from field pieces to the best advantage, should attend to the following particulars.

1. For 16 prs. there are four kinds of case shot; the first, composed of [illegible] balls of [illegible] oz. is never used with the medium charge above [illegible] yards against an enemy drawn up 3 or 4 deep: when they are disposed in deeper order, the distance should be less [illegible] No. [illegible] the second kind is composed of [illegible] balls of [illegible] oz. and its greatest range is 5[illegible] yards, when the enemy is disposed in few ranks: the longest range of the third kind composed of 64 balls of [illegible] oz. is [illegible] yards: the range of the fourth kind composed of [illegible] balls of [illegible] oz. should never exceed 22[illegible] yards.

2. There are 3 kinds of case shot for 8 prs.: the first contains 16 balls of [illegible] oz. and may with the medium charged be fired at the distance of 5[illegible] yards: the second contains 32 balls of [illegible] oz. its range should not exceed 340 yards: the third contains 96 balls of [illegible] oz. and may range 220 yards.

3. For 4 prs. there are but two kinds of case shot: the first contains 16 balls of [illegible] oz. and its range with the medium charge should not exceed [illegible] yards: the second contains 48 balls of [illegible] oz. and its greatest range should be 220 yards.

4. The number of balls in a 16 pr. case being double the number of balls of the same diameter in an 8 pr. case, if the two guns be fired from the same distance with the same initial velocity, the effect of the 16 pr. should be double that of the 8 pr. and the effects of an 8 pr. should be double that of a 4 pr. under the same circumstances: guns of large calibre also ranging farther, there will be still a stronger reason for preferring them to guns of smaller calibre, whenever the nature of the ground and of the service admits of it. If case shot be fired from a 16 pr. with an initial velocity less by $\frac{1}{8}$ than the initial velocity

of caſe ſhot containing balls of equal diameter fired from an 8 pr. and the diſtances be equal; the effects of the 16 pr. will in certain caſes be greater than the effects of the 8 pr.; for the ſame reaſon, the ſhort 8 pr. (66) is ſometimes to be preferred to the common 4 pr. as in the inſtance of the enemy being formed on ſloping ground in figure of an amphitheatre, (as happens in mountainous countries) and very near the battery; the 8 pr. caſe containing double the number of balls that the 4 pr. caſe does, will do more execution.

5. By increaſing the number of balls in the caſe, the initial velocity, and of courſe the effect of each is ſenſibly diminiſhed. When fired againſt troops diſpoſed in very deep order (200) on an amphitheatre of hills, and very near the battery, the greater the number of balls is, the greater the ſlaughter will be; and as in this inſtance, two caſes may be put into the gun at the ſame time, it will be ſufficient if the weight of each be equal to that of the round ſhot.

6. When the enemy is drawn up in very deep order, the medium charge of powder ſhould be preferred to the leſs, both with round and caſe ſhot; the diſtance at which each nature of ſhot ſhould be uſed will be beſt determined by recurring to the preceding theory (206, No. 3), and the reſults of former experiments (211 No. 6).

7. If it be neceſſary in the courſe of a campaign to place ſome 32 prs. in a fixed poſt, five kinds of caſe ſhot ſhould be prepared for them: the firſt with 16 balls of 26 oz. to range 850 yards: the ſecond with 32 balls of 13 oz. the third with 64 balls of 6½ oz. the fourth with 128 balls of 3¼ oz. the fifth with 384 balls of 1 oz. the four laſt may be fired under the reſtrictions already laid down. The two former may be of excellent ſervice in the defence of places at the opening of the trenches; but as the balls ſpread very much, they ſhould be uſed with caution, leſt they hurt the detachments of the garriſon poſted in the advanced works.

213. Balls of hammered iron are the beſt for caſe-ſhot; but, if from motives of œconomy they be made of caſt iron, the metal ſhould be of a hard and tenacious quality, or they will break to pieces at the exploſion: the number that break increaſe in proportion to the augmentation of the charge. Each ſhot therefore before it is put into the caſe, ſhould be placed

placed upon an anvil, and receive a ſmart blow from a heavy hammer; if they ſtand this proof, they are fit for ſervice. The cylinder of tin ſhould be of the ſame diameter as the correſponding round ſhot; one end is cloſed by a wooden cylinder $1\frac{1}{4}$ or $1\frac{1}{2}$ inch thick, on which the firſt row of balls is regularly placed, putting into the interſtices ſmall pieces of wood to keep them firm: the balls of the ſecond row are placed over the interſtices of the firſt, and each row is fixed with chips or ſomething of that kind to prevent their moving, when the ammunition waggons paſs over rough and ſtony roads; which might break the cylinder or deform it, ſo that it would not enter the gun. All the rows of balls being thus diſpoſed, the top of the cylinder is cloſed by a cylindrical piece of wood $\frac{1}{2}$ an inch thick, nailed to the tin, and marked ſo as to be eaſily diſtinguiſhed from the baſe; and on the top is marked the diameter of the balls contained in the caſe, that the artillery men may make no miſtake in the nature of the caſe-ſhot, or in the manner of placing it in the gun.

If maſtic be uſed inſtead of chips, to fix the balls in the caſe, its tenacity will increaſe the force of the powder and the balls will diverge leſs. The beſt maſtic for this purpoſe is made of melted pitch and powdered marble: but the quantity ſhould be proportioned to the force of the charge; for if it be of ſuch tenacity that the caſe reaches the object before it breaks, or breaks very cloſe to it; all the advantage ariſing from the proper divergence of the balls would be loſt: the effect of theſe projectiles being evidently as much diminiſhed by too little as by too great divergence (190).

214. To derive from artillery in field engagements the fulleſt advantages (212), the following rules ſhould be adhered to:

1. Brigades of the heavieſt guns in the army ſhould be poſted at the points whence it is propoſed to make the greateſt efforts againſt the enemy, or where the briſkeſt attack on their part may be expected: and the guns of ſmaller calibre placed ſo as to favour the principal attacks and diſtract the enemy's attention.

2. In poſting brigades of artillery in a defenſive ſituation, a parapet, ditch, hedge, palliſadoe, chevaux de frize, or other obſtacle, ſhould be placed before them, to keep the enemy in check; in caſe they advance with fixed bayonets.

3. There ſhould be to each brigade a reſerve of artil-

lery men covered by an epaulment or the ammunition waggons, to replace without loſs of time any that may be killed or wounded. If it be judged expedient to draw up an army in two lines, that the troops of the ſecond line may in caſe of neceſſity be brought forwards to replace thoſe in the firſt; with equal reaſon ſhould the number of artillery-men be ſufficient to keep up the fire from the cannon with proper vivacity during the whole engagement, in ſpite of any loſs that may be ſuſtained.

## CHAP. VI.

### THE EFFECTS OF THE HOWITZER AND 8PR. COMPARED.

215. IN the laſt century, guns from 6 to 7 feet in length were uſed to project ſtones, caſe ſhot, &c. from beſieged places: the ſhortneſs of theſe guns and the largeneſs of their calibre generally adapted to a ſhot of 24 lbs. gave riſe to the idea of the howitzer; the proportions of which vary among different nations, according to the ſeveral uſes for which they are intended. The longeſt howitzers I ever ſaw were 6 diameters of the muzzle in length of bore, with a cylindrical chamber capable of containing 1 lb. 10 oz. of powder: the bore of the ſhorteſt was 4 diameters of the muzzle in length, with a cylindric chamber containing 1 lb. of powder. The long ones were uſed in the imperial army which Prince Eugene of Savoy commanded againſt the Turks, and the ſhells fired from them are ſaid to have cauſed great deſtruction and diſmay among the Ottoman cavalry. On the other hand, the predilection for this ſpecies of ordnance was much abated at the battle of *Guaſtalla*, fought on the 19th of September 1734; where our cavalry of the left wing was neither diſordered nor hurt by the ſhower of ſhells fired by the enemy, but made ſeveral charges with great effect. As the Ottoman cavalry generally charge in an irregular, deſultory manner, they preſent a much larger object than our cavalry drawn up two or three deep with cloſe files; being therefore very much expoſed, the exploſion of the ſhells will be more deſtructive among them, than in the regular movements and diſpoſitions practiſed by us. Whatever may be the reaſon of this difference, we will only conſider the phyſical effects of projectiles

tiles impelled from a howitzer 6 diameters of the muzzle in length of bore, and compare them with thoſe of the 8 pr. (183), in order to aſcertain the diſorder that each of theſe pieces can ſeverally produce among a body of troops: leaving it to others to diſcuſs the moral effects reſulting from the uſe of howitzer ſhells, which have by many authors been ſuppoſed to be very great: a diſquiſition totally foreign to our purpoſe, as the abſolute conſequences can neither be calculated nor depended on; for it has happened more than once, that troops, which had at the beginning of an engagement been thrown into diſorder by the fire of artillery, have at length recovered themſelves ſo far as to deſpiſe the former object of their fear, on finding that their apprehenſions had greatly magnified the effects of theſe ſeemingly terrific machines.

216. *A ſhell is fired from a howitzer with a view of deſtroying the enemy both by its ſhock, and exploſion on burſting*: its greateſt effects are when, having enfiladed a body of troops and being quite ſpent in ſtriking men or other objects, it burſts in the midſt of thoſe that remain. To convey a juſt idea of the compariſon we propoſe drawing; let the howitzer be equal in length of bore to an 8 pr. of common length, and let them both be loaded with $3\frac{1}{4}$ lb. of powder: the elaſtic fluid on quitting the chamber of the howizer dilates towards the chace, and exerts againſt the ſhell leſs preſſure, than the ſame quantity of fluid generated in the gun exerts againſt the ſhot; conſequently its initial velocity is leſs. As a howitzer 6 diameters of the muzzle in length of bore is only half as long as an 8 pr. and as the largeſt charge for throwing a ſhell 16 lbs. in weight is 1 lb. 10 oz. of powder (215), this projectile muſt have a much leſs initial velocity than an 8 lb. ſhot impelled by $3\frac{1}{4}$ lbs of powder, with the wads well rammed. The initial velocity and the ſpecific gravity of the ſhell being leſs than thoſe of the ſhot, the air's reſiſtance will be greater; and conſequently its penetrations into the ſame butt will be leſs.

217. There are two methods of aſcertaining the effects of howitzer ſhells: the firſt is, by firing againſt a butt at different elevations and diſtances, and comparing the penetrations of the ſhell with thoſe of a ſhot fired from an 8 pr. The reſult will expreſs the proportion between the effects of the two projectiles, though the hole made by the howitzer ſhell will be much larger than that made by the ſhot: but the velocity

velocity with which the ſhell impinges on the butt and its ſpecific gravit being leſs than thoſe of the ſhot, the penetrations, provided the butt be of a proper conſiſtence, will be leſs than would reſult from the formula $f \ldots D u^2$ (182).

The ſecond method, is to find the initial velocity of the ſhell fired at different elevations (167.)

As the difference between the elevations and the correſponding velocities will be greater in the ſhell than in the ſhot; it will be neceſſary, after having aſcertained the initial velocity and the value of $r$ = the reſiſtance of the air, to find the remaining velocity = V and ſubſtitute its value in the formula $D u^2$, in order to obtain the penetrations of the ſhell ſuppoſing it to be ſolid: but as its weight is leſs than the ſpecific gravity of a ſphere of ſolid iron of the ſame diameter, the expreſſion $D u^2$ muſt be diminiſhed in the ratio of its actual weight to its weight when ſolid; which will then nearly give the abſolute penetration to be compared with that of the ſhot.

218. Theſe experiments having been made with a $5\frac{1}{2}$ inch howitzer and $r = 12$ for the reſiſtance of the air to a 32 lb. ſhot, the remaining velocities of the ſhell fired with proper elevation to ſtrike the butt at the different diſtances are inſerted in the following table, and alſo the correſponding relative penetrations, ſuppoſing the ſhell to be ſolid and the butt eaſily penetrable.

| The velocity with which the ſhell impinges. | Yards. | Feet. | Relative penetrations. |
|---|---|---|---|
| Shell fired cloſe to the butt | | 472 | $5\frac{1}{2} \times 472^2$ |
| At the diſtance of | 340 | 364 | $5\frac{1}{2} \times 364^2$ |
| At the diſtance of | 680 | 286 | $5\frac{1}{2} \times 286^2$ |

The weight of the howitzer ſhell being to a ſolid ſphere of iron of the ſame diameter as 7 to 10, the above penetrations will be reduced to $\frac{7}{10}$ and will be as follows:

| | Yards. | | Relative penetrations. |
|---|---|---|---|
| Shell fired cloſe to the butt | | | 2359 |
| At the diſtance of | 340 | — | 1404 |
| At the diſtance of | 680 | — | 869 |

On

On comparing these penetrations with those of the 8 lb. shot (183) the number of men in file that the shell can pass through from the different distances will be found in round numbers.

| | Yards. | | Number of men destroyed by a shell. |
|---|---|---|---|
| Fired close to them | | — | 5 |
| At the distance of | 340 | — | 3 |
| At the distance of | 680 | — | 2 |

219. To derive from the howitzer shell the fullest effects, it should burst in the midst of a body of troops, and its power of movement be quite exhausted in passing through the obstacles it meets with before it burst.

To determine the effects of the splinters, let some howitzer shells burst in the midst of a number of dead animals and their effects be carefully observed. The result in general will prove that the splinters of a shell will not pass through the thickest parts of a man's body; and if it burst in the midst of a number of men, not more than four of those nearest to it will be wounded: by adding to the possible effects of the shock (218) those of the splinters, we shall ascertain how many men can be killed or wounded by a howitzer shell.

Number of men killed or wounded.

| | Yards. | By the shock alone. | | By the shock and splinters. |
|---|---|---|---|---|
| Fired close to them | | 5 | — | 9 |
| At the distance of | 340 | 3 | — | 7 |
| At the distance of | 680 | 2 | — | 6 |

The number of men wounded and disabled will be greater, if the least resisting parts of the body be struck, as was remarked in the case of cannon shot.

220. On comparing the effects of a shell and shot [illegible] it is apparent that in respect to the shocks alone, not only common 8 prs. but even short guns fired with the least charge are more destructive than the howitzer, and that the only advantage the latter has over them is when the shell bursts at 680 yards. A howitzer shell sent against the [illegible] of an army will seldom range 680 yards, and even then it is mere chance, if it burst in the midst of a body of men, should not this happen, or should it by accident break against a [illegible]

a ſtone, or the fuze be extinguiſhed by falling into ſoft ground, its effects will by no means equal the effects of the ſhot.

221. The remarks on the penetrations of ſhells compared to ſhot will preciſely apply to the length of their reſpective richochets. That the firſt graze of the ſhell and ſhot may be at the ſame diſtance, the howitzer muſt be more elevated than the gun; the ſhell conſequently will not ſo eaſily reach its deſtination, the angle of incidence being leſs acute its force will be more deadened by the fall, and its richochets ſhorter and fewer.

222. To aſcertain the effects of a howitzer loaded with caſe ſhot equal in weight to the ſhell, it ſuffices to remark that the initial velocity of each ball is equal to the initial velocity of the ſhell (207): which being found by experiment, and a round of caſe ſhot fired at the ſame angle of elevation, the penetrations of the balls may be eaſily determined (205). Suppoſe the balls be projected from different diſtances, then on comparing the relative penetrations with thoſe in the preceding table (205), or with others produced by velocities leſs than 1450 feet, it will give the ratio between the effects of caſe ſhot fired from a howitzer and a gun. The initial velocity of a ſhell fired horizontally or nearly ſo, is about 474 feet; the following will be the penetrations of the caſe ſhot.

| Weight of balls. | | Very near the butt. | | At the diſtance of 170 yards. |
|---|---|---|---|---|
| oz. | | | | |
| 6½ | — | 803 | — | 138 |
| 3½ | — | 640 | — | 59 |
| 1 | — | 444 | — | 6 |

On comparing this with the former table (205), the penetrations of balls projected from a howitzer placed cloſe to the butt, are to thoſe of balls of equal diameter impelled from of a gun with an initial velocity of 1450 feet; as 803 : 7580; or as 10 : 94 nearly: and at the diſtance of 170 yards, as 138 : 4624; or as 1 : 33 nearly.

223. But as the howitzer contains three times as many balls of the ſame diameter as the 8 pr. and 6 times as many as the 4 pr. this difference ſhould be likewiſe eſtimated. To this end, the relative ſituation of the troops againſt which they are fired muſt be conſidered.

Suppoſe a howitzer and an 8 pr. to be on the ſame plane with

with the enemy and equally diſtant from them; the number of men in the firſt rank ſtruck by the caſe ſhot from the howitzer and by that from the gun will be in the ratio of the baſes of the two cones, that is leſs than 3 : 1; each man ſtruck by the howitzer, will be touched by more balls than one: but when the enemy is drawn up in very deep order, the caſe ſhot from the gun will make more havock, as from the greater velocity, it will pierce a whole file; and the greater the diſtance, the more will its effects exceed thoſe of the howitzer, on account of its greater remaining velocity = V. To make the compariſon clearer, ſuppoſe circumſtances the moſt advantageous to the howitzer; viz. that at 170 yards, it ſtrikes triple the number of men; under this ſuppoſition, its greateſt effects will be to thoſe of the gun as $3 \times 138 : 4642 :: 1 : 11$.

224. Again, if the enemy be drawn up on a riſing ground in form of an amphitheatre, and ſo near that each ball may ſtrike one man; the effects of the howitzer will be to the 8 pr. as 8 : 1 and to the 4 pr. as 6 : 1: but if three rounds of caſe ſhot be put at once into the 8 pr. it will regain its ſuperiority, the number of balls being then equal, and the initial velocity of thoſe projected from the gun, being greater by $\frac{1450}{3}$ (200) than of thoſe projected from the howitzer; they will range farther and do more execution: the 8 pr. is therefore to be preferred. It was ſhewn in the former part of this work, that there is no danger of the gun burſting, if 3 caſes be fired at the ſame time; and this has been fully confirmed by experience. On comparing a howitzer 6 diameters of the muzzle in length of bore, and a common 4 pr. charged with 1 lb. 10 oz. of powder; the latter, except when the enemy is very near and drawn up on an amphitheatre of hills, will be more deſtructive than the former. If the length of the howitzer be curtailed, the difference will be ſtill greater.

225. In conſtructing howitzers, that from the great ſize of the chambers may project ſhells with a greater initial velocity and from the increaſed diameter contain larger ſhells, the preceding reflections ſhould be had in view: the carriage and the wheels, for inſtance, ſhould be made ſtrong enough to reſiſt the greateſt efforts of a large quantity of powder. But when the ſhell is projected with twice the initial velocity ſuppoſed in the courſe of this compariſon, the howitzer will yet be inferior to the 8 pr.

226. There

226. There are particular caſes however, where the howitzer may be very uſeful; as in the attack of poſts where the enemy is perfectly covered from cannon ſhot: the ſhells from the curve line that they deſcribe may then be of excellent ſervice; or, in the attack of towns or villages, where large quantities of ſtraw, hay, faggots, or other combuſtible materials are depoſited. Some pieces of port fire compoſition may be put into the ſhell, which on burſting will communicate the flame to every thing around: by theſe means, towns and magazines may be eaſily ſet on fire.

227. The howitzer may in the following caſes be uſeful in the attack and defence of places.

1. In a fortified town, when the caſemates or caponieres are too narrow to admit guns of the common length; howitzers are then preferable to ſhort guns of cylindric bore, as the exploſion of guns of large calibre ſoon deſtroy the embrazures.

2. To prevent as much as poſſible the inconveniencies ariſing from the ſmoke in caſemates and caponieres, and yet be able to project caſe ſhot with the greateſt initial velocity; the howitzers may be lengthened if there be ſufficient room; this will in ſome meaſure bring back the *pierrier* guns formerly in uſe.

3. In the attack of places, ſome howitzers may be planted on the batteries deſigned to fire à richochet, to enfilade the covert way and its branches: eſſential ſervice will be derived from this mode of uſing them; ſince beſide the deſtruction they may cauſe among the beſieged, they ſoon ſilence the fire of the infantry, and cover the workmen in carrying on the approaches.

## CHAP VII.

### OF SHELLS PROJECTED FROM MORTARS.

228. THIRTEEN and 10 inch mortars are much uſed in ſieges: 15 inch mortars are now generally diſuſed; as from their great weight when properly reinforced, and the ſize of their chambers, they were very difficult to work on the batteries: when the thickneſſes of metal are diminiſhed and the chambers reduced in ſize, their ranges are ſo much ſhortened, that the ſhells do not fall with more force than thoſe

thoſe projected from 13 inch mortars; they are moreover very cumberſome and heavy.

229. The principal advantages to be derived from ſhells may be reduced to the three following;

1. In ſieges, to diſmount the enemy's artillery and bombard cities.

2. To ſet fire to and overthrow works, and produce havock and diſorder among troops.

3. To break through the vaulted roofs of barracks, magazines, caſemates, caponieres and other military edifices, that have not been conſtructed with ſufficient ſtrength to reſiſt the ſhock.

Ten inch mortars are generally adequate to theſe purpoſes; hence on principles of œconomy, 13 inch mortars are ſeldom uſed, unleſs the diſtance be too great for the ſmaller mortars: their figure being the ſame, their longeſt ranges are nearly in the ratio of 4:5. Of ſhells of the ſame conſtruction, the largeſt are undoubtedly the beſt for ſetting fire to buildings, eſpecially when ſome pieces of port fire compoſition are put into them: the ſplinters are more deſtructive to works and buildings than to men, and the harſher the quality of metal of which the ſhell is caſt, the greater number of pieces it will burſt into.

Shells made of a very tenacious iron are beſt adapted for penetrating the vaulted roofs of barracks, magazines, &c. that on coming in contact with a hard body, they may not break before they explode: by diminiſhing the interior cavity of the ſhell, the force of the ſhock and its reſiſtance to the exploſion are much increaſed.

230. Our anceſtors, in eſtabliſhing the proportions of ſhells, conceived that the thickeſt part ſhould be oppoſite to the fuſe; that from its ſuperior weight, it might always come firſt to the ground, and in ſtriking againſt hard bodies be leſs liable to break. Hence they ſuppoſed alſo, that the ſhell, though buried in the earth, would always burſt, ſince the fuſe would remain uppermoſt; but experience has proved that theſe effects do not always take place, owing to the rotatory motion of the ſhell; the force of which overcoming the preponderance of the heavy part or bottom, makes it fall on every ſide indiſcriminately; and when it enters a cloſe compact ſoil which ſtops any communication between the fuſe and the external air, the fire is ſoon ſmothered and extinguiſhed. When the fuſe is not driven far enough into the

the ſhell, it frequently happens that the ſhell beginning to turn before it quits the mortar, the head of the fuſe ſtrikes againſt the muzzle, and breaks off; thus, if the fire has not penetrated beyond the eye of the ſhell, it may reach the object but will not burſt.

231. The difference in the form and ſize of the chambers, the various purpoſes for which they are uſed, and the different qualities and modifications of powder render it neceſſary to alter the charges and elevations of mortars.

In the largeſt mortars, the initial velocity of a ſhell increaſes in proportion to the charge; hence to obtain the greateſt initial velocity, the chamber ſhould be filled with the ſtrongeſt powder, a tompion of wood placed immediately over it, and both the tompion and ſhell ſurrounded with ſifted earth well rammed; that from the increaſe of reſiſtance, the inflammation of the powder may be more inſtantaneous, and the fluid more abundant and elaſtic. An increaſe of elevation alſo adds to the initial velocity, even with equal charges; ſince from the greater reſiſtance oppoſed to the exploſion in this poſition of the mortar, the fluid generated in the chamber acquires, before the ſhell begins to move, greater denſity.

The ſame effects do not take place in muſquets, though fired at different elevations (Treatiſe on Powder).

To prove that the initial velocity of a ſhell is modified by the elevation; fire the ſame mortar with two equal charges, but at different elevations; for inſtance, at 70° and 20°: the ſhell will range much farther at 70° than at 20°; though, from the theory of projectiles, fired *in vacuo*, the ranges ſhould be equal; and fired in the open air, the ſecond ſhould be the longeſt. By varying the charge of powder in the ſame mortar, it has been found, that there is a particular elevation which with each charge gives a longer range than can be obtained from the ſame charge at any other elevation; wherefore mortars ſhould not be fixed in their beds at a certain elevation, as from the theory of projectiles many have imagined ſhould be the caſe. The elevations that give the longeſt ranges, differ very ſenſibly in two mortars of different calibres, but of ſimilar proportions, charged with a quantity of powder proportionate to the weight of their reſpective ſhells, and the ſize of their chambers.

232. It is evident, therefore, that a knowledge of the various circumſtances that conduce to the effectual uſe of mortars

mortars, muſt be founded on theory, and derived from ſcience (142, 231); conſequently the generality of bombardiers are very ill-qualified for this ſervice: but from the ſmall number of officers, there being freqently a neceſſity during a ſiege, of leaving the direction of mortar batteries to the bombardiers, a particular form of inſtruction has been expreſsly made out for their uſe, calculated for unſcientific men, that they may be enabled to do their duty with propriety and effect. For this purpoſe the uſe of ſhells is reduced to two principal caſes; (229) the firſt conſiſts in diſmounting the enemy's artillery, deſtroying buildings, ſetting fire to and overturning works, and cauſing diſorder among troops: the ſecond, in breaking through caſemates that have not been properly conſtructed.

233. It is ſufficient in the firſt caſe (232) that the ſhells be projected with juſtneſs, without much regard to the force of the ſhock; this may be attained by obſerving the following inſtructions, which are within the comprehenſion of every man. The bombardiers ſhould practiſe with 13 and 10 inch mortars of the common conſtruction; afterwards with ſome of the ſame calibre, but with chambers of different dimenſions, in order to convince them that a difference in the ſize of the chamber conſiderably affects the length of the range.

1. They ſhould know the elevation that gives the longeſt range, when the chambers are filled; and alſo the beſt elevation and charge for firing from the batteries conſtructed in the firſt and ſecond parallels, when the beſieged town and the batteries are in the ſame plane.

2. They ſhould be made to obſerve that a difference in the form of the chambers in mortars of the ſame calibre, induces a neceſſity of altering the elevation, and alſo affects the range; and that with the ſame mortar, the ranges diminiſh in proportion as the elevation is greater or leſs than that which gives the longeſt range.

3. They ſhould be taught always to load the mortar in the ſame manner, when the ſame charge is uſed; ſince to negligence or miſtake in this particular, may be attributed many of the varieties that occur in the lengths of ranges: and that with the ſame charge, the error that may tend to ſhorten the range, will not add much to the deflection of the ſhell.

4. As a difference in the quality of the powder, in the moiſture and temperature of the atmoſphere, conſiderably affects the ranges, they ſhould be taught to make allowance for theſe circumſtances, by elevating or depreſſing the mortars; by increaſing or decreaſing the charge.

5. They ſhould fire at a butt with the degree of elevation that gives the longeſt range, and increaſe or diminiſh the charge till they ſtrike the object: this will convince them that leſs irregularity enſues from altering the charge, than from altering the elevation; for the more the elevation deviates from that which gives the longeſt range, generally between 40° and 50°, the more irregular are the ranges.

6. When the object is to fire at troops or enfilade works, it is better to lay the mortars at ſmall elevations, that the ſhells may not bury themſelves.

7. When the plane of the mortar battery is below the plane of the object, it is much eaſier to project the ſhells with juſtneſs, than when they are both on the ſame, or the mortar on the higher plane.

234. The ſecond caſe (232) viz. to break through caſemated buildings, requires much theoretical knowledge in the officer charged with the execution of this piece of ſervice, in order to determine the ſituation of the mortar, its proper charge and elevation; that the ſhell may impinge on the object with the greateſt poſſible force. Suppoſe a ſhell projected from the point A, in the direction A P (Pl. 6, Fig. 22) has deſcribed a curve A F N B L of the fourth kind; in order to determine the force that the projectile has in each point of this curve, the direction and quantity of compound velocity at each point muſt be found. For this purpoſe it is neceſſary to have a ſcale of the ſpaces paſſed through in times of unequal movement (170, 172) from whence may be deduced the ſcale of correſponding velocities: then, to aſcertain the direction and quantity of compound velocity at the point B, in the perpendicular line B P, make B E equal to the correſponding velocity at this point, of a movement B P unequally accelerated by gravity; draw E H parallel to A P, and equal to the velocity which at the ſame point B correſponds to the retarded movement of impulſion A P; then the right line H B will expreſs the direction and quantity

tity of compound velocity, which the ſhell has at the point B (168).

235. From the conſtruction (234) it appears;

1. That if the point F repreſent the vertex of a curve, F C will expreſs the horizontal direction which the ſhell has at that point, and the quantity of compound velocity, which is leſs than the ſhell can have in any other point of the curve.

2. That the compound velocity at the point N increaſes in proportion to the diſtance of N from F: that the direction of the compound velocity forms a very acute angle with the horizon, when the point N is very near to F, is leſs acute in proportion as N is farther diſtant from F, and becomes a right angle when the ſhell has loſt its movement of impulſion; which in practice is always greatly below the plane A B: the velocity of the projectile is then reduced to the unequally accelerated movement of gravity.

3. That the angle formed by the direction of the ſhell with the horizon, approaches nearer to a right angle, in proportion as the angle P A B is leſs acute: on the contrary, when the mortar is fired at a very ſmall elevation, the angle formed by the direction of the ſhell and the horizon, can only become a right angle, in a point L far diſtant from the horizontal line B A.

236. The formula $m\,V \times \frac{a}{\text{whole ſine}} = f$ (178) ſerves to expreſs the force of the ſhock of a ſhell againſt a plane, of which the inclination is given; the application of this formula will be rendered more familiar by the following remarks:

1. The force of the ſhell N increaſes, in proportion to its diſtance from the vertex F of the curve; ſince its compound velocity alſo increaſes (235, No. 2): the force of the ſhell at the point B being expreſſed by $m\,V = m \times B\,H$ is greater than its force at the point F, becauſe B H is greater than C F.

2. If the ſhell at the vertex F ſtrike at right angles a vertical plane, it will impinge with all the force expreſſed by $m\,V = m \times C\,F$; ſince in this caſe, the quantity $a$ being equal to the whole ſine, the expreſſion $\frac{a}{\text{whole ſine}}$

repreſents unity: on the contrary, if the ſhell at the point F meet a horizontal plane, $a=o$; in this caſe, there will be no ſhock, and the ſhell will roll upon the plane.

3. If the ſhell ſtrike the point B in the plane Z $y$ inclined to the horizon with a direct ſhock, its force will be to the force of a ſhock on the horizontal plane B Q, as the whole ſine is to the right ſine $=a$ of the angle of incidence H B Q: wherefore, if the ſhell inſtead of ſtriking the horizontal plane B Q, ſtrike the inclined plane I O, the force of the ſhock will be leſs; and will be in the proportion of the right ſine of the angle of incidence H B I to the ſine of the angle H B Q.

4. If two ſhells be projected from two mortars of different calibres, but of ſimilar proportions, fired with the largeſt quantity of powder, and with the ſame degree of elevation; the largeſt ſhell will have the moſt force in the correſponding points of the curves, owing to its ſuperior weight, and greater compound velocity (229); ſince it deſcribes a larger curve.

5. If two ſhells of different diameters, fired as above, in correſponding points of their curves ſtrike two objects in differently inclined planes, the ſhock of the leaſt ſhell may exceed that of the largeſt; becauſe the angle of incidence of the latter may be moſt acute.

237. To ſtrike with a direct ſhock, and with great force, a ſuperficies whoſe poſition is given (234); it is neceſſary:

1. To place the mortar ſo that the axis produced may cut the vertical plane of the object; and that the curve deſcribed by the ſhell, be at right angles to it at the point of impact.

2. To uſe the largeſt quantity of powder that the chamber of the mortar can contain.

3. To obſerve the relative poſition and figure of the given ſuperficies, whether flat, or convex like the roof of a caſemate; whether horizontal or inclined.

4. Thence to determine the diſtance that the mortar ſhould be placed from the object and its proper elevation.

238. It is obſerved, that the curve deſcribed by ſhells does not always cut the vertical plane of the object, in the direction of the axis of the mortar, but deflects from it ſo as to deſcribe a double curve. The ſolid ſphere of bronze projected

projected from the *eprouvette-mortar*, when it reaches the vertex of the curve, deflects either to the right or left, though it be very denſe, and its ſurface very ſmooth. The deflection of ſhells, whoſe ſpecific gravity is leſs, and centre of gravity diſtant from the centre of the figure, and which from the ears and the head of the fuſe preſent an uneven ſurface to the air is greater: the fuſe, from the rotation of the ſhell round its axis, deſcribes a kind of *picciloide*.

This deflection does not much diminiſh the force of the ſhock on a flat, but on a convex ſuperficies its effects are very conſiderable; for, however ſmall the deflection may be to the right or left, the angle of incidence inſtead of being right, becomes very acute. This circumſtance merits a more particular examination:

239. Suppoſe in the firſt place, that the ſuperficies B to be impinged be flat and horizontal like the ramparts of forteſſes, (Pl. 6, Fig. 22) under which are caſemated barracks or magazines, covered with thick layers of earth well rammed: in order to break through theſe caſemates, the mortar ſhould be placed in Q very near to the point B, and laid at a very high elevation, as 75° or 85°, that the angle of incidence may be nearly a right angle. If the diſtance from B to Q be ſhort, and the plane of the mortar much higher than B, the compound velocity of the ſhell will be greater, ſince the angle of incidence approaches nearer to a right angle, and the force of the ſhock will be greatly increaſed: the reverſe will happen if the mortar be much lower than the object; inſomuch, that if the ſhell on reaching the vertex of its curve, meet a horizontal plane, it will roll upon it without penetrating (236). This firſt ſuppoſition is the moſt favourable to the effect of ſhells, the vertical plane cutting the plane of the object at right angles; and the given ſuperficies being generally of great extent, the mortar may be placed ſo, that the ſhell will always fall on it, in ſpite of any trifling irregularity in the length of the range.

240. Suppoſe in the ſecond place, that the plane to be impinged, be *y* B Z, inclined to the horizon A B; the mortar muſt then be removed ſo much the farther from B towards A, as the angle A B *y* is the greater; the axis of the mortar produced ſhould paſs through a vertical plane, ſuppoſed to cut Y Z at right angles. The diſtance between the mortar and object, and the proper elevation for giving a

direct ſhock, muſt be determined from a knowledge of the two unequal movements that form the curve (170, 172); and the initial velocity produced at a certain elevation, known by previouſly firing a few rounds to aſcertain the quality of the powder. But if the law of the two unequal movements cannot be obtained, the officer muſt have recourſe to the treatiſe on curves, and their greateſt amplitudes; in order to determine the diſtance A B, and the angle of elevation, taking notice that in general theſe inclined planes form with the horizon angles from 30° to 45°, and that the initial velocity of the ſhell increaſes in proportion to the greater elevation of the mortar: by properly combining theſe circumſtances, he may, without removing the mortar a great way from the object, procure an oblique ſhock of greater force than the direct ſhock that could be obtained at a greater diſtance with a leſs initial velocity; ſince the greater the diſtance the leſs will be the elevation, and the leſs, of courſe, the initial velocity. Under this ſecond ſuppoſition, deflections to the right or left do not much diminiſh the force of the ſhock, but a very ſmall error in the amplitude is ſufficient to prevent the ſhell from impinging on the object; ſince theſe planes, in the direction of the mortar, are of no great extent, and from their inclination, the ſhocks would become ſo oblique, that the end propoſed could by no means be attained (236, No. 3).

241. Suppoſe in the third place, that the ſuperficies be convex, as the roof of a caſemate turned with a circular arch: the mortar ſhould be placed as near to it as poſſible, that from the higher elevation, the ſhell may have a greater velocity; and in the direction of the keys of the arches, that notwithſtanding any ſmall variation in the amplitude, they may ſtill be of ſervice: the leaſt deflection will be ſufficient to render the ſhock, which ſhould be direct, very oblique. Again, if the ſuperficies be convex, in form of a dome, the ſlighteſt error in the direction or range will greatly diminiſh the force of the ſhock; ſince this ſuperficies declines on every ſide from the perpendicular: wherefore, it is of all others the moſt difficult object to ſtrike with a direct ſhock.

242. When the officer has determined the beſt ſituation for directing the mortars againſt the objects he propoſes to bombard; he will inform the bombardiers of the proper elevation and quantity of powder, and point out every particular that can conduce to the better execution of the ſervice:

vice: the bombardiers having been already trained at the ſchool of practice (233) will be enabled to execute with preciſion and efficacy the order they receive.

243. In bombarding military edifices, the ſhells may fall on ſolid works of maſonry, built upon arches, or on ſoft ſubſtances, as earth, &c. with which arches are frequently covered, to ſecure them from ſhells. When they fall on ſolid works of maſonry, they tend by their ſhocks to penetrate and ſplit the caſemates, and by their exploſion to overturn the counterforts, and ſhatter the walls.

Arches conſtructed on the principles laid down in the firſt and ſecond books of Military Architecture, are capable of reſiſting the moſt violent ſhocks from 13 inch ſhells: their reſiſtance increaſes when they are conſtructed of the beſt materials, in a climate favourable to their acquiring great tenacity; and when they are contiguous to ſolid and immoveable bodies.

In buildings totally detached from others, or built on eminences, the counterforts ſhould be ſo proportioned, as not only to reſiſt the preſſure of the vaulted roofs, but every ſhock to which they may be expoſed from ſhells.

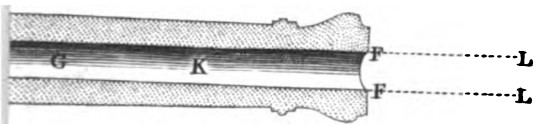
244. All the effect of a ſhell falling upon a ſolid work of maſonry built on arches, is reduced, if the arch be well turned and made of choice materials, to a ſmall excavation in the place where it falls: it even often happens that the ſhell breaks before it burſts, particularly when caſt of brittle iron. But if the arch be not firmly ſupported, the counterforts not ſufficiently ſolid; or in inſulated buildings not well proportioned to reſiſt the ſhock, and the unneceſſary thickneſs which maſons generally give to the arches, under the idea of rendering them impenetrable; the ſubſtances in too ſmall a maſs, as in detached powder magazines; or the ſtone of of ſo elaſtic a nature, as conſiderably to increaſe the ſhock; (Treatiſe on Moving Bodies) in all theſe caſes the ſhells will produce the deſired effects. A ſhell on penetrating a brick arch, makes a hole nearly circular, if the bricks be of a good quality: but if from the negligence or ignorance of the workmen, the materials be bad or badly worked up; or if owing to the climate, they have not acquired a ſufficient degree of tenacity, the ſhell, beſide making a hole, will ſplit and ſhatter the building.

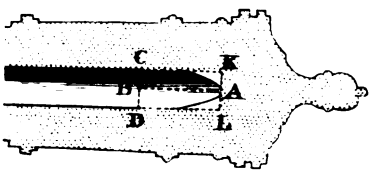
245. Shells falling on arches covered with earth or other ſoft materials (243) bury themſelves without doing any mate-

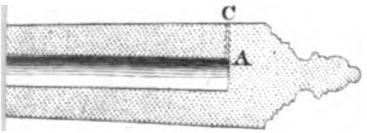
rial injury, if the earth has been properly prepared (Military Architecture). Arches of this kind will ſuſtain no damage from 10 inch ſhells, nor will the building be much ſhattered if the counterforts are of proper dimenſions: the only danger is that the exploſion of the ſhell may carry off a part of the circumjacent earth; ſo that by a number of ſhells falling on the ſame ſpot, the top of the arch may be entirely uncovered, and, in the event, pierced through. Thoſe that wiſh to enter more particularly into the conſtruction of military edifices, to enable them to reſiſt the force of ſhot or ſhells, may refer to the fifth book of Military Architecture, where the ſubject has been fully diſcuſſed.

A TREA-

*Plate 1.st*

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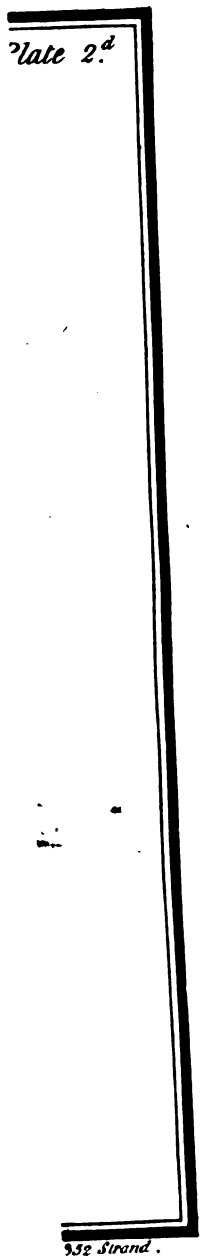
Plate 2.d
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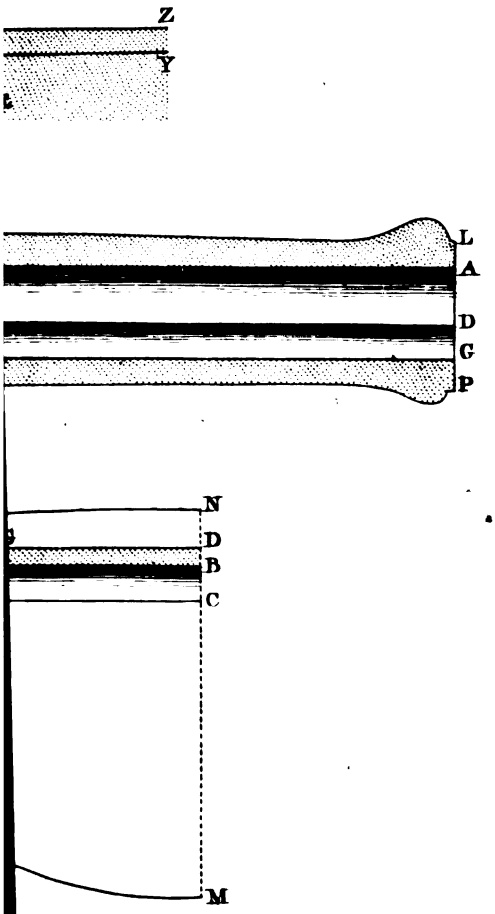


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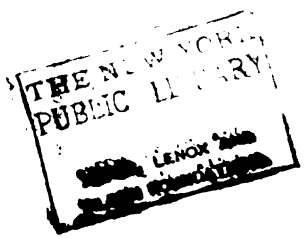
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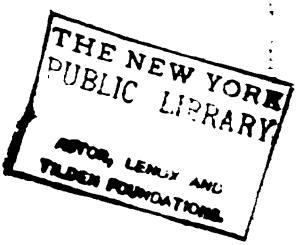
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Plate 4.th

Fig 11.

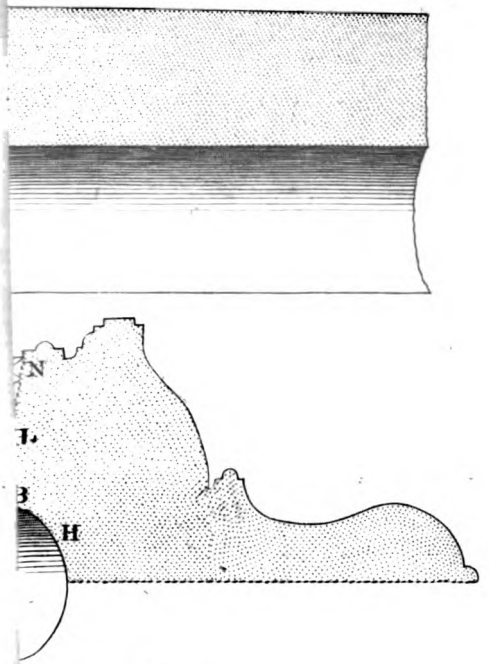
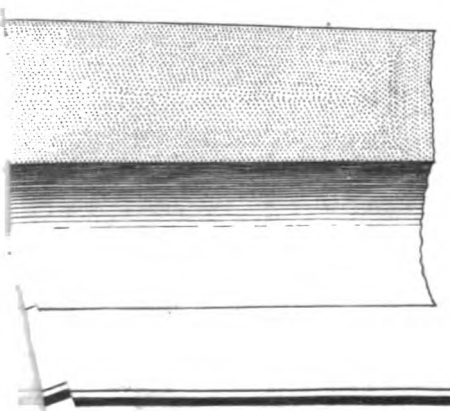



Fig 13.



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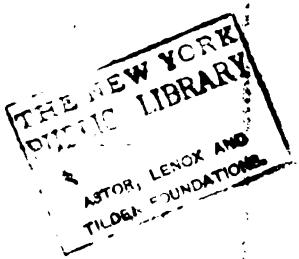
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A

# TREATISE

ON THE

# SERVICE OF ARTILLERY

IN

# TIME OF WAR.

1. IN all well conſtituted governments, the arſenals and places of ſtrength are furniſhed in time of peace with artillery, ammunition and ſtores of all kinds, ſufficient to check the ſudden incurſions of any of the neighbouring powers; without incurring any unneceſſary expence, or purchaſing any articles that are of a periſhable nature. Hence, as the peace eſtabliſhment of troops is ſmall, and the magazines are unprovided with many things indiſpenſably requiſite for the ſervice in time of war; whenever there is reaſon to apprehend its approach, new levies are made, proviſions and ammunition purchaſed, the magazines filled, the fortifications repaired and mounted with cannon, carriages for tranſporting ſtores and baggage provided, and a corps of officers, non-commiſſioned officers, and drivers formed for taking care of the horſes belonging to the field-trains of artillery.

The proportion of each is regulated by the nature of the country, and the kind of war that may be expected; whether offenſive or defenſive; in the capacity of principals, or auxiliaries; whether the ſcene of operations be in an open champaign

champaign country, or in one interſected by rivers and canals, or divided by impenetrable foreſts, extenſive moraſſes, or lofty mountains.

2. The ſtores to be depoſited in the magazines during peace, conſiſt principally of thoſe articles that are difficult to procure in time of war, or that require much time to manufacture and prepare; as arms and iron work of all kinds, ſhot, ſhells, and every thing that muſt be brought from foreign countries: deferring the collection of thoſe that can be procured at home, or are liable to be damaged by keeping, as wood, linen, &c. till the eve of the declaration of war.

3. Taking it for granted then, that the arſenals and places of ſtrength are abundantly provided with every thing requiſite for carrying on a war of any continuance; that the royal corps of artillery is ſufficiently numerous; and that the non-commiſſioned officers and ſoldiers are fully acquainted with the inſtructions compiled for their uſe in 1770; I propoſe in this work, to enlarge upon the principal duties of the ſuperior and ſubaltern officers, that the cadets having thereby an opportunity of knowing the duties attached to each particular ſtation, may be enabled to aſcertain what may be expected from them on every emergency.

4. The object of an artillery-officer, in the time of war, *is to derive the greateſt poſſible advantage from the uſe of cannon, mortars, fire-works and mines.* The knowledge requiſite for attaining this may be conſidered as two-fold: the one has reſpect to the planning of enterprizes, in which artillery is employed; the other is ſolely confined to the executive part.

5. In the planning of every enterprize there are ſix points to be previouſly conſidered. The firſt is its nature and object: is a fortreſs for example, to be attacked or defended? to conſider, whether the attack can be beſt carried on by regular approaches, by aſſault or blockade; and in a caſe of defence, whether the greateſt efforts of the garriſon ſhould be exerted at the beginning, or reſerved for the latter end of the ſiege; whether the ground will admit of countermines being uſed with effect; or whether the fortifications be of ſuch a conſtruction, as to enable the garriſon to diſpute the ground inch by inch with the beſiegers.

6. In the ſecond place, an officer ſhould be well grounded in the principles of fortification and tactics, as well as in the theory of artillery; and ſhould be maſter of the practice in every

every part. There are certain particulars that ought to be aſcertained, before an officer can ſafely give his opinion: in the caſe, for inſtance, of his being conſulted about forming a field train of artillery; he muſt, before he is competent to decide, be acquainted with the nature of the country, the plan of operations and the ſtrength of the army; that the quantity of artillery may be adequate to every object propoſed by the commander in chief, without being ſo numerous as to embarraſs or retard the movements of the troops.

7. In the third place, he ſhould adapt every thing ſo judiciouſly to the nature of the ſervice, that they may all concur with preciſion to the attainment of the object in view, without unneceſſary trouble or expence.

8. Having decided on the means to be employed; the fourth conſideration is, how to employ them to the beſt advantage; or the enterprize may at laſt prove abortive: for victory depends not more on the number of troops, than on the diſpoſition that is made of them; and a train of artillery ſufficient for the reduction of a fortreſs may become inadequate to the purpoſe, through injudicious management.

9. Under the fifth head, are claſſed the diſpoſitions for carrying any project into execution (5); they are as it were the ſoul of the enterprize; for by them all the various parts of the ſyſtem are put into motion and made to concur to the ſame point; whereas a want of concert might render all the previous meaſures ineffectual and be productive of nothing but confuſion. A certain number of perſons are made acquainted with the leading ſteps that have been taken to enſure its ſucceſs, and the plan laid down for carrying it into execution in a given time.

10. And laſtly, to render the event ſucceſsful, all accidents capable of deranging the plan ſhould be carefully guarded againſt. In this, reſpect muſt be had both to the object itſelf and to every collateral incident. If it be intended, for example, to diſpatch a convoy of artillery by land; a ſufficient number of pioneers and carpenters ſhould be ſent forward to mend the roads, and repair the old or make new bridges, that the march of the convoy may not be impeded by the breaking down or overſetting of any of the carriages. Is a poſt to be ſurprized? the different bodies of troops deſtined for this ſervice ſhould be provided with truſty guides, perfectly acquainted with the country; and every precaution taken by the officers commanding the ſeveral diviſions

viſions to prevent deſertion, leſt the enemy be apprized of the deſign.

11. The plan being thus digeſted, the execution follows: and firſt, the officer charged with the conſtruction of the firſt battery at a ſiege will determine from obſervation, whether by direct firing, he ſhould endeavour to diſmount the enemy's artillery, and beat down the defences; by richochet firing, enfilade the works and harraſs the beſieged; or by firing with red-hot ſhot ſet fire to the buildings.

He will, in the ſecond place, reconnoitre the ground, that the battery may be erected on the moſt advantageous ſpot.

He, will in the third place, aſcertain what number of men, and what quantity of tools and materials are wanted for its conſtruction.

Fourthly, he will conſider the means of employing every thing to the greateſt advantage, that the battery may be conſtructed in the beſt manner, and in the ſhorteſt ſpace of time poſſible.

Fifthly, he will divide the workmen into different parties, directing theſe to throw up the earth in digging the ditch, in order to form the battery; thoſe to piquet down the faſcines: ſome to ram the earth; and others to bring the materials from the grand magazine.

Laſtly, he will take every precaution to guard againſt miſtakes in throwing up the works, or cutting the embrazures during the night; and to prevent the ſeveral detatchments from miſſing their way, or interrupting each other in tranſporting the ammunition, &c. to the battery. The ſubaltern and non-commiſſioned officers will inſpect the conduct of the workmen, and take care that they do their duty.

12. The circumſtances that ariſe in the execution of an enterprize frequently induce a neceſſity of deviating from former ſyſtems, and ſometimes even of varying the whole diſpoſition to the great embarraſſment of young officers: they ſhould therefore be practiſed in the ſolution of different problems beſt calculated for exerciſing their inventions, and obliging them to have recourſe to their own minds for reſources in caſes of novelty and difficulty, but which yet require inſtant determination and execution. Such is the path trod by all military men that aſpire to eminence in their profeſſion; and ſuch is the road by which officers have arrived at diſtinction and renown.

The

The diviſion of this work is into three parts: the firſt treats of the ſervice of artillery in the attack; the ſecond, in the defence of fortified towns; and the third comprehends the various other branches of artillery ſervice in the field.

# FIRST PART.

## Of the Service of Artillery in the Attack of Fortified Towns.

13. WHENEVER a town fortified according to rule is intended to be taken by ſiege, the object of the beſieger is to make a breach; which may be effected by the means of heavy artillery, or of mines: and the execution, in either caſe, reſts with the royal corps of artillery.

## CHAP. I.

### Of the first Diſpoſitions to be made for Beſieging a Place in form.

14. THE firſt duty of an artillery officer, when it is reſolved to lay regular ſiege to any place, is to make out a ſtate of the guns, mortars, ammunition, machines, and carriages of all kinds requiſite for that purpoſe. To be enabled to make a proper proportion of ſtores, the commanding officer of artillery muſt be maſter of certain data (6); that is to ſay, the commander in chief, or the general officer charged with the direction of the ſiege, ſhould communicate to him a plan of the fortifications and environs of the place, accompanied with ſuch profiles and remarks, as may enable him to aſcertain what fronts are moſt attackable; with the advantages and diſadvantages attending each attack; both

both with reſpect to the works and countermines, the nature of the ſoil where the trenches muſt be opened, and the ſeveral heights and hollows in the vicinity of the town. He ſhould likewiſe be informed of the enemy's force; viz. whether the town be protected by an intrenched camp, or left ſolely to the exertions of the garriſon: if it be amply provided with artillery, proviſions, ſtores and caſemates; if the garriſon be ſufficiently numerous; and whether compoſed of veteran troops or new levies; if the governor be in high eſtimation for his military talents: if the town be populous, and whether the inhabitants are well affected to the garriſon, and of a martial or pacific diſpoſition. The commanding officer of artillery ſhould be likewiſe acquainted with the nature of the country, through which the ſtores, &c. muſt be tranſported; as the diſpoſitions that ſerve for tranſport by land will by no means anſwer for water carriage.

15. But if it be impoſſible to collect ſufficient intelligence to regulate the quantity of artillery and ſtores, the proportion muſt be formed on the general principles of attack. On his arrival in camp, the engineers ſhould impart to him the obſervations they have been able to make on the place and its environs; and the commander in chief ſhould communicate whatever intelligence he may have received from his correſpondence within the town; the original ſtate of ordnance and ſtores may be then varied and adapted to circumſtances, that the ſiege may be carried on with proper vigour. The roads that the laſt convoy muſt take to reach the camp ſhould be covered from the enemy, till all the ſtores are ſafely arrived.

16. If the officer intruſted with making out the ſtate of ordnance and ſtores be ſufficiently acquainted with the place and its environs, he ſhould aſcertain (according to the fundamental maxim of all beſiegers) againſt which front the attack can be made, the *leaſt expoſed and with the greateſt expedition:* and examine whether the ſiege can be beſt carried on by regular approaches; by taking advantage of any defect in the ſituation, to break ground cloſe to the works; or by blockade: and whether the former and latter parts of the direct attack will be ſimilar. By the aid of this inveſtigation, the quantity and quality of ſtores wanted for a ſiege may be determined with the greateſt accuracy; but it will be better

better to increaſe the proportion, if the eſcorts be large; and to diminiſh it, when few troops can be ſpared for this ſervice.

17. The primary conſideration towards deciding the number and calibre of the pieces of ordnance, is *to keep up conſtantly a fire ſuperior to that of the place.*

The following are the particular rules for the obſervation of this maxim, in the firſt part of the direct attack;

1. The proportion of 32 prs. for firing at the principal defences of the place, and covering the approaches to the creſt of the glacis, ought to exceed by a third at leaſt, the number that the garriſon can bring to bear on the attack, from the body of the place, or any of the outworks, capable of making a long reſiſtance.

2. The proportion of 16 prs. for diſmounting the enemy's artillery in the ravelins, and other advanced works that may retard the progreſs of the beſiegers, ſhould exceed by a fourth at leaſt, the number of guns in thoſe works.

3. The richochet firing is from 8 and 4 prs. the number for enfilading any works ſhould never be leſs than three.

4. Each of the works attacked ſhould be enfiladed by at leaſt three 10 inch mortars, when the object is to diſmount the enemy's artillery; and, by perpetually annoying them, oblige them to abandon their works. But if the baſtions be caſemated, the mortars ſhould be 13 inches in bore, and the number increaſed.

5. As the richochet firing may be ſtopped for fear of incommoding the workmen in completing the third parallel, two or three royal mortars ſhould be planted in the ſecond parallel, againſt each face of the covered way, to harraſs the garriſon during the ceſſation of the richochet-firing.

6. Some ſtone mortars may likewiſe be placed in the finiſhed parts of the third parallel, for firing into the covered way.

18. Having determined the nature and number of the ordnance requiſite for the firſt part of the attack, the quantity neceſſary for the ſecond is then reſolved on; making uſe, for this purpoſe, of the guns planted in the firſt erected batteries, which ceaſe firing when a lodgment is effected on the creſt of the glacis.

19. This

19. This artillery (17, 18) is only deſigned for firing againſt the front of the attack; but if there be any objects within the town expoſed to the fire of the beſiegers, the ordnance muſt be proportionably increaſed. If the barracks and the magazines, for inſtance, can be cannonaded, a proportion of 32 prs. ſhould be deſtined for this ſervice; 16 prs. will be ſufficient for beating down the houſes, &c. and 8 prs. for projecting red-hot ſhot to ſet fire to buildings. When the barracks and magazines are covered from cannon-ſhot, but not ſecured from ſhells, the number of 13 inch mortars for breaking through the caſemates ſhould be increaſed: in caſe the troops or ſtores are lodged in the common edifices of the city, 10 inch mortars will ſuffice for the bombardment.

20. The number of rounds fired from each gun and mortar againſt the front of the attack; is eſtimated at 60 rounds a day. From the damage that may be done to the batteries by the fire of the place, the accidents that will inevitably happen, and the occaſional ſuſpenſion of the firing, this calculation is ſeldom exceeded; it may therefore be conſidered as the expenditure of every gun or mortar mounted on the batteries, from the day they are opened till the end of the ſiege.

21. The calculation for the guns intended for firing againſt barracks and magazines, (19) is from 250 to 300 rounds a gun for each 32 pr. when the diſtance is ſhort, and the line of direction nearly perpendicular to the objects: but for longer diſtances, and very oblique directions, the number of rounds muſt be regulated by the ſituation of the place, and it's environs; on the principles laid down in the third book of Military Architecture, and the Philoſophical Inſtitutions, with regard to the effect of cannon-ſhot on walls. Large ſhells are the beſt for penetrating caſemates; to produce the full effect, the mortars ſhould be laid between 35° and 45°, and the ſhells projected with the greateſt initial velocity ſhould fall perpendicularly to the plane of the object.

22. The number of gun-carriages and mortar-beds, as well as ſpare articles of every kind, is proportioned to the duration of the ſiege: we generally compute three carriages for every two guns, and two beds for each mortar, when the ſiege is expected to laſt about a month; the proportion is increaſed for longer ſieges.

The

The number of beds for each mortar is likewiſe increaſed, when the chambers are to be filled with powder; as the ſhocks are then very violent, and ſoon render them unſerviceable.

The quantity of tools for the pioneers, and for making faſcines and gabions, are regulated by the works that are intended to be thrown up; whether lines of circumvallation, or only approaches and batteries on the front of the attack.

The quantity of powder is computed from the number of rounds (20), and the propertion for each charge; this is in general eſtimated at $\frac{3}{8}$ of the weight of the ſhot for large guns, and half of the weight of the ſhot for guns of ſmaller calibre The common charge for 13 inch mortars, including that of the ſhell, is $12\frac{1}{4}$lbs. of powder; $6\frac{1}{2}$lbs. for the 10 inch mortar, and $3\frac{1}{4}$lbs. for royal mortars; the charge for the ſtone mortar is 4lbs. of powder, and for hand grenades, $3\frac{1}{4}$oz.

23. When artillery, ſtores, &c. are tranſported by land, oxen, horſes, and ſometimes mules, are uſed for drawing them. The weight that two oxen will draw on tolerably level ground, is about 9 cwt. two horſes or mules will draw about $7\frac{1}{4}$ cwt.: in hilly countries, the weight ſhould be diminiſhed by a fifth.

The weight in cannon being more concentrated than in common carriages, five pair of oxen are harneſſed to a 16 pr. mounted on it's carriage, weighing $36\frac{1}{2}$ cwt.; whereas, four pair would ſuffice, if the weight were divided into four equal parts. In mountainous countries, the ammunition, tools, &c. are carried on beaſts of burthen: a common mule will carry a weight of $2\frac{1}{3}$ cwt. and a full load for one of the ſtrongeſt, is $2\frac{3}{4}$ cwt. but every article that exceeds $1\frac{1}{2}$ cwt. ſhould be put into carriages. It is much more expeditious and œconomical to make uſe of boats, if there be any rivers or navigable canals in the country, that the convoys are to paſs through: to determine the number, the ſize of the boats muſt be known, and the ſoundings of the rivers; as the freight of each muſt be proportioned to the depth of water.

24. To exemplify the above maxims, let us ſuppoſe;

1. A fortified town N N (Pl. 1), is to be beſieged in form: that the nature of the ſoil is favourable for carrying on the approaches, and conſtructing the batteries; and that the adjacent country is level, and

neither particularly advantageous nor diſadvantageous to the beſieger.

2. That the works are reveted; the revetements of the common thickneſs; the height of the body of the place about 40 feet; and of the counterſcarp, about 20 feet; the profiles juſt, and the works mutually flanking each other; no countermines, but caſemates and magazines covered from cannon-ſhot; and an ample proviſion of ſtores of all kinds.

3. That from 16 to 18 guns may be mounted on the faces A, B, of the baſtions in the front A B that is attacked; and the ſame number upon the four faces C, D, E, F, of the ravelins.

4. That the garriſon is ſufficiently numerous, compoſed of veteran troops, and commanded by experienced and gallant officers.

25. The firſt ſtep towards making out the proportion of artillery for laying ſiege to the ſuppoſed fortreſs, (Pl. 1) is to draw a plan of the attack; and then determine the number and nature of the pieces of ordnance, on the principles before laid down: the following will be the reſult;

Twenty-four 32 prs. for the royal battery G.

Twenty-four 16 prs. for the batteries H, K.

Twelve 8 prs. for the richochet batteries M, O.

Twelve mortars; four of 13 inches, and eight of 10 inches, to be diſtributed in the batteries L, N.

Twelve royal mortars to be placed in the ſecond parallel, for covering the ſappers in the third parallel, when the richochet firing ceaſes.

Six ſtone-mortars to be placed at Q, in the third parallel, to annoy the beſieged in the covered way.

26. Upon the ſame principles may be computed the quantity of artillery neceſſary for the ſecond part of the direct attack: it will be nearly as follows;

(Pl. 2.) Five 32 prs. for battering in breach the ravelin P from A.

Four 32 prs. for ſilencing from the battery B, the guns on the baſtion Q which covers the ravelin P.

Eight 32 prs. viz. five for battering in breach the baſtion from C, and three to be planted in the battery O.

Six 32 prs. for firing from D againſt the upper and lower flank R.

Three

Three ſtone-mortars to fire from the battery E againſt the ravelin P.

Three ſtone-mortars to fire from the battery F againſt the flank R, which covers the breach N in the baſtion Q.

Eight 13 and 10 inch mortars to fire from the battery G againſt the flank R; on a ſuppoſition that its fire is ſuperior to the counter battery D.

Eight royal mortars to harraſs from the battery K the troops that defend the ravelin P.

Eight mortars of different calibres, to harraſs from the battery H the troops that defend the baſtion Q; and prevent them from throwing up intrenchments.

According to this calculation, the artillery uſed in the firſt part of the attack, will be amply ſufficient for the ſecond.

27. The number of rounds for each piece is determined by the duration of the ſiege. In the caſe in queſtion, the greateſt number of days that the batteries will be open, will be nearly as follows;

(Pl. 1.) The batteries G, H, K, L, M, NO, twelve days.

The royal mortars in the ſecond parallel, eight days.

The ſtone mortars at Q in the third parallel, ſix days.

(Pl. 2.) All the batteries conſtructed for the ſecond part of the attack, eight days.

28. The following is a proportion of ſtores for carrying on a regular ſiege, under theſe circumſtances (24): the whole is ſuppoſed to be ſupplied from one depôt, and tranſported to the ſcene of action, in carriages drawn by oxen along level and well made roads. This ſtate will alſo ſerve as a rule for ranging each article, in the claſs to which it properly belongs.

State of Artillery, Ammunition, and Stores of all kinds, for laying regular Siege to a fortified Town N N.

| No. and Nature of Ordnance. | No. and Nature of Gun-carriages. | No. of Pairs of Oxen. | No. of Carts. |
|---|---|---|---|
| 24 Heavy 32 prs. carried on 24 block waggons, with draught chains for 8 pairs of oxen to each ..... | ..... | 192 | — |
| 24 Heavy 16 prs. mounted on travelling carriages with limbers and draught chains for 5 pairs of oxen to each | ..... | 120 | — |
| 12 8 prs. mounted on travelling carriages, with limbers and two pairs of oxen to each | ..... | 24 | — |
| 60 Guns. | 36 Carriages for 32 prs. with limbers and side arms at 2 pairs of oxen each ..... | 72 | — |
| | 12 Spare carriages, with limbers for 16 prs. and 36 sets of side arms | 12 | — |
| | 6 Spare carriages with limbers, and 18 sets of side arms for 8 prs | 6 | — |
| | 54 Carriages. | | |
| 6 Stone mortars<br>4 13 inch ditto<br>8 10 inch ditto | Carried upon 7 block carriages with draught chains, for 5 pairs of oxen each ..... | ..... 35 | — |
| | Carried over | 461 | — |

12 Royal

| No. and Nature of Ordnance. | | Pairs of Oxen. | Carts. |
|---|---|---|---|
| | Brought over | 461 | — |
| 12 | Royal ditto, carried in 2 common carts, with 2 pair of oxen each | 4 | 2 |
| 30 | Mortars 60 Mortar-beds at 2 to each mortar | 22 | 22 |
| | 60 Sets of ſide arms for the mortars | 1 | 1 |
| | **Spare Articles.** | | |
| 4 | Block waggons, at 2 pairs of oxen each | 8 | — |
| 24 | Wheels ſhod with iron for 32 and 16 pr. carriages | 12 | 12 |
| 12 | Wheels ſhod with iron for 8 pr. and block ditto | | |
| 100 | Axle-trees for carriages of all ſorts | 10 | 10 |
| 200 | Spunge-ſtaves for guns | 4 | 4 |
| 100 | Sheep-ſkins for ſpunges | 1 | 1 |
| | **Shot, Shells, and Grenades.** | | |
| 28800 | Shot for 32 prs. at 1200 rounds a gun, and 40 to each cart | 720 | 720 |
| 17280 | Shot for 16 prs. at 720 rounds a gun, and 80 to each cart | 216 | 216 |
| 7200 | Shot for 8 prs. at 600 rounds, and 160 to each cart | 45 | 45 |
| 2400 | Caſe-ſhot, half for 32 prs. the other for 16 prs. | 45 | 45 |
| 4800 | 13 inch ſhells, at 1200 rounds for each mortar, and 7 ſhells to each cart | 686 | 686 |
| 9600 | 10 inch ſhells, at 1200 rounds for each mortar, and 15 ſhells to each cart | 640 | 640 |
| 11520 | Royal ſhells, at 840 rounds for each mortar, and 40 ſhells to each cart | 288 | 288 |
| 12000 | Hand grenades, at 500 to each cart | 24 | 24 |
| | Carried over | 3187 | 2716 |

| | | Pairs of Oxen. | Carts. |
|---|---|---|---|
| | Brought over | 3187 | 2716 |
| | **Shot, Shells, and Grenades continued.** | | |
| 5500 | Fuzes for 13 inch mortars } | | |
| 11000 | Ditto for 10 inch ditto ... } Packed up in } | 12 | 12 |
| 13000 | Ditto for royal ditto ..... } ſand bags .... } | | |
| 15000 | Ditto for hand grenades .. } | | |
| 4000 | Bottoms of wood for the ſtone mortars .... | 16 | 16 |
| 4000 | Baſkets for ditto ..... | 40 | 40 |
| | **Machines and Cordage.** | | |
| 600 | Hand-ſpikes ..... | 10 | 10 |
| 400 | Coins ..... | 8 | 8 |
| 10 | Long levers with horſes ..... | 3 | 3 |
| 8 | Gins complete ..... | 4 | 4 |
| 2 | Capſtans with ropes } ..... | 2 | 2 |
| 6 | Hand jacks ..... } | | |
| 6 | Ropes for guns, 25 fathoms each ..... } | | |
| 4 | Ropes for gins, 15 fathoms each ..... | | |
| 20 | Double ſlings ..... | 12 | 12 |
| 100 | Ropes for tying the ammunition upon the waggons, 8 fathoms each ..... | | |
| 100 | Drag ropes, 10 fathoms each ..... } | | |
| 26 | Cwt. of cordage for tying and packing .... | 4 | 4 |
| | **Ammunition.** | | |
| 5922 | Whole barrels of corned powder, viz. .... | 647 | 647 |
| *cwt.* *qrs.* *lbs.* | | | |
| 2635 1 12 | For 28800 rounds from 32 prs. at 10¼lbs. ..... } | | |
| 790 2 24 | For 17280 rounds from 16 prs. at 5⅛lbs. ..... } | | |
| 105 1 20 | For 7200 rounds à richochet, at 1 lb. 10 oz. 4 dr. ..... } | | |
| 527 0 16 | For 4800 rounds for the 13 inch mortars, at 12 lbs. 4 ozs. 12 drs. including the charge for the ſhell } | | |
| | Carried over | 3945 | 3474 |

Ammunition

| cwt | qrs. | lbs. | | Pairs of Oxen. | Carts. |
|---|---|---|---|---|---|
| | | | Brought over | 3945 | 3474 |
| | | | Ammunition continued. | | |
| 562 | 1 | 4 | For 9600 rounds for the 10 inch mortars, at 6 lbs. 8 oz. 14 drs. .... | | |
| 337 | 1 | 9 | For 11520 rounds for the royal mortars, at 3 lbs. 4 oz. 7 drs. | | |
| 146 | 1 | 20 | For 4000 rounds for ſtone mortars, at 4 lbs. 1 oz. 9 drs. ..... | | |
| 21 | 3 | 24 | For 12000 hand grenades, at 3 oz. 4 drs. ..... | | |
| 512 | 2 | 0 | For the infantry, at $\frac{3}{8}$ of an oz. for each muſquet cartridge ..... | | |
| 282 | 3 | 1 | To ſupply the waſte and loſſes, being in the proportion of $\frac{1}{20}$ of the whole ..... | 2 | |
| 91 | 0 | 0 | Of match ..... | 10 | 10 |
| 1830 | 0 | 0 | Of muſquet balls including 91 cwt. of piſtol bullets ..... | 200 | 200 |
| 150000 | | | Flints ..... | 4 | 4 |
| 660 | | | Oil-cloths for covering the powder and match ..... | | |
| | | | Various Articles. | | |
| 2000 | | | Oak planks for the platforms ..... | 200 | 200 |
| 1000 | | | Sleepers for ditto ..... | 50 | 50 |
| 1000 | | | Fir planks for the frame of the gallery of deſcent into the ditch ..... | 70 | 70 |
| 500 | | | Beams for ditto ..... | 30 | 30 |
| 40000 | | | Sandbags ..... | 16 | 16 |
| 5000 | | | Ballaſt baſkets ..... | 35 | 35 |
| 150 | | | Cuiraſſes with caſques for the ſappers .... | 6 | 6 |
| 91 | | | Cwt. of greaſe for the axle-trees and the laboratory ..... | 10 | 10 |
| | | | Carried over | 4576 | 4105 |

| | Pairs of Oxen. | Cartt. |
|---|---|---|
| Brought over | 4576 | 4105 |
| **Iron-work and Nails.** | | |
| 54 Cwt. of iron of ſorts for the wheels and axletrees of gun carriages | 6 | 6 |
| 36 cwt. — Of forge iron in bars and rods | 4 | 4 |
| 9 cwt. — Of ſteel<br>29 cwt. — Of nails for wheels<br>54 cwt. — Of nails for platforms<br>5 cwt. — Of nails of 40 to the lb.<br>3 cwt. — Of iron wire | 10 | 10 |
| **Articles for the Laboratory.** | | |
| 36 cwt. — Of mealed powder | 4 | 4 |
| 36 cwt. — Of refined ſaltpetre | 4 | 4 |
| 18 cwt. — Of flowered ſulphur | 2 | 2 |
| 45 cwt. — Of tar | 5 | 5 |
| 45 cwt. — Of pitch | 5 | 5 |
| 4 cwt. — Of packthread<br>3 qrs. 8 oz. Of common thread<br>3 cwt. — Of flax<br>3 qrs. Of fine tow<br>4 cwt. — Of glue<br>3 qrs. — Of yellow wax<br>2 cwt. 2 qrs. Of wax candles (Packed in boxes) | 2 | 2 |
| 1246 Yds. of barras<br>1246 Yds. of linen and cotton cloth<br>10 Reams of fine writing paper<br>10 Ditto of common paper<br>40 Oil-cloths for covering the above articles | 6 | 6 |
| Carried over | 4624 | 4153 |

Inſtruments

| | Pairs of Oxen. | Carts. |
|---|---|---|
| Brought over | 4624 | 4153 |
| **Inſtruments for the Laboratory and work-ſhops.** | | |
| 3 Mealing tables with treſtles | 2 | 2 |
| 40 Wooden troughs for mixing fuſe compoſition<br>20 Heavy mallets for fixing fuſes<br>40 Setters for driving ditto<br>60 Drifts for ditto<br>30 Ladles for ditto<br>24 Small bruſhes for glue | 2 | 2 |
| 24 Tin funnels of different ſizes for loading ſhells and grenades<br>50 Raſps with handles<br>50 Drawing knives<br>6 Sieves of hair or fine ſilk<br>6 Hand ſaws<br>12 Pair of ſciſſars of ſorts<br>30 Augers and gimblets<br>6 Handſcrews<br>12 Gouges<br>4 Pair of pincers<br>150 Tin meaſures of different ſizes<br>150 Can-hooks for ſhells<br>100 Quadrants<br>1000 Pricking wires<br>100 Lanterns of ſorts<br>60 Wire ſieves<br>1 Bench for carpenters<br>6 Buckets<br>10 Pails<br>2 Large melting pots with iron trivets<br>2 Small ditto<br>6 Small axes<br>12 Hand bills<br>Steels, flints matches and tinder boxes | 3 | 3 |
| Carried over | 4631 | 4160 |

Intrenching

| | | Pairs of Oxen. | Carts. |
|---|---|---|---|
| | Brought over | 4631 | 4160 |
| | **Intrenching Tools.** | | |
| 5000 | Pick-axes of kinds | 100 | 100 |
| 10000 | Mattocks with helves, ſuppoſing there are no lines of circumvallation to conſtruct | | |
| 600 | Spades with helves | 5 | 5 |
| 300 | Axes of ſorts | 25 | 25 |
| 1000 | Hand bills | | |
| | **Tools for forty Miners.** | | |
| 20 | Iron mallets | 3 | 3 |
| 200 | Jumpers and gads | | |
| 20 | Hammers with heads and points | | |
| 20 | Cutting hammers | | |
| 40 | Trowels | | |
| 20 | Small ſpades for cutting | | |
| 2 | Searchers in ſeveral pieces | | |
| | **Tools for thirty Carpenters.** | | |
| 10 | Croſs cut ſaws | 4 | 4 |
| 20 | Common ditto | | |
| 30 | Broad axes | | |
| 20 | Hammers | | |
| 10 | Sledge ditto | | |
| 150 | Chiſſels and gouges of ſorts | | |
| 300 | Augers and gimblets | | |
| 6 | Hand vices | | |
| 10 | Iron crows | | |
| 6 | Planes | | |
| 10 | Pairs of pincers | | |
| | Carried over | 4768 | 4297 |

Tools

| | Pairs of Oxen. | Carts. |
|---|---|---|
| Brought over | 4768 | 4297 |
| Tools for ten Blackſmiths | | |
| 2 Forges complete, with anvils and ſtocks .... | 2 | 2 |
| 20 Pairs of forge tongs of different ſizes ..... | | |
| 8 Nail borers ..... | | |
| 15 Hammers ..... | | |
| 8 Sledge ditto ..... | 3 | 3 |
| 40 Files of ſorts ..... | | |
| 2 Benches with beak irons and vices ..... | | |
| 2 Preſſes ..... | | |
| Spare carts and oxen with each convoy ..... | 87 | 48 |
| Total | 4860 | 4350 |

The miners tools contained in this inventory, are for working under ground, and piercing the wall of the counterſcarp; but if the ſoil be rocky or very hard, there muſt be a greater proportion of iron picks and ſteel gads; and the following articles ſhould be added: iron jumpers caſe-hardened at the points; ſmall iron ſcrapers for clearing the holes; needles for charging them; common iron crows of different ſizes; picks pointed with ſteel; cutting mallets with ſteel edges; and mallets with caſe-hardened points.

29. Should it be intended to attack two fronts at once; the quantity of guns, mortars, ammunition and tools of all kinds muſt be increaſed in proportion to the extent and ſerioufneſs of the ſecond attack.

If only one front be attacked, and the works difficult to beat down; as when conſtructed of hard turf, 900 or 1000 cwt. of powder muſt be added to the quantity in the inventory: ſince after having made openings in the revetement with cannon ſhot, the miners muſt be introduced for the purpoſe of making practicable breaches; and the number of rounds allotted for the mortars in the ſecond parallel muſt be augmented by about $\frac{1}{3}$, that the garriſon may be continually harraſſed till the operations of the miners are compleated. If the works be of common earth with one ſtage of countermines; the above-mentioned quantity of powder muſt be allowed for the mines and mortars, and a third added to the quantity intended for the direct firings from the firſt batteries,

ries, that a conſtant firing may be kept up againſt the defences of the place, while the miners are buſied in exploring the countermines: with two ſtages of countermines, the number of rounds for the mortars muſt be doubled, and at leaſt four times the quantity of powder provided for the attack of the countermines, together with planks and joiſts for the ſhafts and galleries. When there are no out-works on the front attacked, the artillery and ſtores deſigned (28) for the attack of the ravelin may be omitted. If the profiles of the out-works are too narrow to admit of cannon, the 16 prs may be left out of the inventory: as the fire from the 10 inch mortars will in this caſe be ſufficient againſt the ravelin.

30. Theſe obſervations have reference only to the place itſelf: but there are others to be made on the nature of the adjacent country, and the choice of carriages for the tranſport of ſtores. If the fortreſs be ſituated among mountains, where it is difficult or perhaps impoſſible to uſe wheel-carriages, a greater number of capſtans with ropes and pullies, both ſingle and double, muſt be provided, that every neceſſary article may be brought forward by men. If the ſoil be ſo rocky as not to furniſh a ſufficient quantity of earth for the conſtruction of the batteries, a proper number of ſacks filled with earth and wool muſt be tranſported to the ſpot.

If the town be ſurrounded with rivers or broad canals, ſome wooden or leather boats with their apparatus ſhould be provided, together with a large quantity of treſtles and every other thing requiſite for conſtructing bridges, for the paſſage of the artillery and ſtores, and for keeping the communication open between the ſeveral parts of the attack. If the ſtores be tranſported in boats or waggons, the oil-cloths for covering the powder, match, and other combuſtibles, ſhould be much larger than when they are carried on beaſts of burthen: when the latter expedient is adopted, ſtrong nets muſt be provided for holding the ſhot and ſhells; the weight put into each package ſhould never exceed $1\frac{1}{2}$ cwt.

31. When the whole or a part of the ſtores for the ſiege is drawn from any fortified town, it ought to be as far diſtant as poſſible from the theatre of war: ſhould it of neceſſity be a frontier town, the commanding officer of artillery ought to ſignify it to the perſons at the head of his department, that the ſtores he has taken away may be inſtantly replaced; leſt from ſome accident, the ſyſtem of the war be ſuddenly

ſuddenly changed, and the enemy take advantage of the unprovided ſtate of the town to attack it.

Guns that are not perfectly good will anſwer very well for richochet firing and for battering in breach: when there are any ſuch, therefore, in the town from whence the ſtores are drawn, they ſhould be included in the inventory, and after the ſiege be condemned and ſent to the foundry: likewiſe any powder, carriages, cordage, ſand-bags, or other ſtores that have been kept too long in the magazines; ſince a commanding officer of artillery may by ſkilful and judicious arrangements employ them very uſefully, without detriment to the ſervice, yet greatly to the intereſt of his ſovereign, by ſaving the money that the purchaſe of new articles would coſt.

Finally, if there be reaſon after the trenches are opened to apprehend that the obſtinacy of the garriſon may ſo far protract the ſiege, as to render the ſupply of ammunition inadequate to the reduction of the place, the commanding officer of artillery ſhould give timely intelligence to the perſons charged with ſupplying his department, that the operations may not be retarded or ſuſpended.

32. The following return ſhews the leaſt number of officers, non-commiſſioned officers and privates for the ſervice of the artillery at a ſiege under the preſuppoſed circumſtances (28).

| | | |
|---|---|---|
| A commanding officer | | |
| Second in command | | |
| Major | | |
| An adjutant and aſſiſtant | | |
| Captains | 12 | |
| Subalterns | 36 | |
| Serjeants and corporals | 92 | |
| Bombardiers and gunners | 700 | |
| | | 840 |
| Sappers | 80 | |
| Miners | 40 | |
| Artificers for laying platforms and bridges | 40 | |
| | Total | 1000 |

Beſide theſe, a detachment from the line muſt aſſiſt the bombardiers and gunners in conſtructing the batteries, and working

working the artillery; and a few ſteady intelligent men picked out for carrying on the ſap. With one ſtage of countermines, the number of miners muſt be increaſed to 80, and with two to 160. The infantry muſt furniſh ſome fit men for working under ground, and building the frames of the ſhafts, branches and galleries.

## CHAP. II.

### Of Convoys.

33. THE tranſport of artillery and ſtores is either by land, or water: in the former caſe, a rendezvous is appointed for all the carriages, and the roads are put in repair; in the latter, the boats are collected at the place moſt commodious for embarkation.

So ſoon as the commanding officer of artillery has received orders from the general to forward the guns, ſtores, &c. contained in the inventory previouſly concerted between them; he diſpatches an experienced officer to the camp, the moment he hears that the place is inveſted, to chooſe a proper place for the park; and when the convoy marches by land, he detaches one or two ſubaltern officers to examine the condition of the roads and bridges, that they may be repaired, or rebuilt if neceſſary: in the mean time, the ſtores are loaded and every thing prepared for departure.

34. The roads ſhould be broad and ſtraight, for the ſake of ſhortening the line of march, and avoiding the delay that ſometimes happens in narrow roads to a whole convoy from the breaking down or overſetting of a carriage, particularly of a heavy gun. In a mountainous country, where the roads are ſteep, narrow and winding; they ſhould if poſſible be widened and mended: if that cannot be effected, new ones muſt be made ſufficiently broad and ſtraight. A ſteep road is leſs inconvenient than a winding one; the difficulty in the firſt caſe being ſurmounted by dividing the ſtores into a number of carriages; but in the ſecond, from the ſhort turns, the guns muſt frequently be dragged on ſleighs by the ſoldiers with the aſſiſtance of ropes and tackles, with great labour and much loſs of time.

35. Bridges, for the paſſage of heavy artillery, are made either with beams, treſtles, or boats. Should there be a neceſſity

neceſſity for paſſing without delay a deep ditch leſs than 20 feet in breadth, ſix or ſeven beams may be taken from the neareſt houſes or villages: when there are none within reach, ſome trees meaſuring 4 or 5 feet in girth ſhould be inſtantly felled, and when ſtripped of the branches laid acroſs the ditch, at about ten inches diſtant from each other; and upon them a layer of boughs, or any wood that can be more eaſily procured, 12 or 14 feet in length, and 4 or 5 inches in thickneſs; and the ſurface made ſmooth with a coat of earth or turf. If no trees large enough for this purpoſe can be found, or the ditch is more than 20 feet wide, a firm and ſubſtantial bridge may be made by placing a treſtle in the middle of the ditch, and reſting the ends of the trees upon it; or in lieu of the treſtle, a thick piece of timber ſupported at each ſide by two beams fixed in the banks; this croſs piece will be ſtrong enough to ſupport the ends of the trees reſting on it.

36. Bridges on treſtles can only be laid over canals, or rivers that are not ſubject to floods; as in caſe of a large ſwell they would be in danger of being carried away. The treſtles are generally made on the ſpot of well-ſeaſoned timber that ſquares from 8 to ten inches. Their height above the ſurface of the water ſhould be at leaſt 3 feet, and the croſs piece that forms the head 12 or 14 feet long: the diſtance between every two treſtles is 14 or 16 feet; and when the bottom of the canal or river is not rocky or gravelly, their feet are nailed upon ſquare wooden frames, to prevent their ſinking. Six pieces of timber, 7 or 8 inches ſquare, called *baulks*, are laid on the treſtles, and the ends nailed down; the whole breadth from outſide to outſide of the baulks is from 10 to 12 feet, and over them are two layers of planks or cheſſes $1\frac{1}{2}$ inch in thickneſs, and 12 or 14 feet in length. When the timber is green, the thickneſs ſhould be increaſed by $\frac{1}{3}$; and, in lieu of planks, any wood that is 4 or 5 inches thick may be nailed on, and covered with turf or earth as before-mentioned (35).

37. If the river be ſubject to freſhes or very deep, the bridge is made of boats faſtened together two and two by ſix well-ſeaſoned baulks from 6 to 8 inches ſquare, and of ſuch a length, that the ends reſt on the outer gunnel of each boat, after leaving an interval of eight feet between every two boats; they are nailed down to the gunnels of the boats, and covered with planks two inches thick and 14 feet

feet long; a ſecond layer of planks 1½ inch thick, and 10 feet long is laid tranſverſely. The pairs of boats thus faſtened together are placed at 8 feet diſtant from each other, joined by baulks 6 or 8 inches ſquare and 10 feet long, nailed down to the gunnels, and covered with cheſſes as before. To every two boats there is an anchor, and a cable from each to hold them againſt the ſtream; and when from its great rapidity this is found inſufficient, a ſheer-line from each boat is made faſt to the banks of the river. Rails 4 feet high are placed along each ſide of the bridge for the ſafety of paſſengers.

If the river be navigable an opening is occaſionally made in the bridge, by placing the center pair of boats almoſt contiguous to thoſe on each ſide, and joining them by baulks that are not nailed down; thus, they may be eaſily removed to give a paſſage to any boats or veſſels paſſing up or down.

To render the bridge more ſecure againſt ſwells, large ſtakes are driven into the bed of the river, at the places where the anchors lay, and the boats are faſtened to them with ſtrong cables. And when there is any reaſon to apprehend that the enemy have a deſign of ſending down with the current, boats filled with combuſtibles to ſet fire to the bridge, a ſtrong iron chain ſhould be ſtretched acroſs the river, and ſupported by ſtakes at about 1½ foot above the ſurface of the water.

38. When the bridges are made, and the roads repaired, the train of artillery, &c. ſets off, divided into ſeveral convoys: for if the whole moved at once, the line of march would be nearly 17 miles; ſince each pair of oxen takes up at leaſt 10 feet, and each carriage about the ſame. The diſtribution ſhould be made into four parts; this will enable the officers to pay more attention, will render the march leſs troubleſome and tedious, and they will be more amply ſupplied with proviſions and forage on the road.

In the firſt convoy ſhould be ſent the intrenching tools of all ſorts, that the troops may proceed to throw up lines and open the trenches, together with every article belonging to the laboratory, and a certain proportion of ſhells and powder; that the laboratory may be inſtantly eſtabliſhed, and the neceſſary preparations made for the enſuing ſiege.

The ſecond convoy ſhould be compoſed of the guns intended for the royal battery, the mortars for the ſecond parallel,

parallel, and about 200 rounds of ammunition for each gun; together with the ſleepers and planks for the platforms.

In the third convoy ſhould be forwarded the guns and ſtores that will be ſooneſt wanted; and the fourth ſhould include every other article contained in the inventory. A ſtore keeper and deputy ſhould accompany each convoy: a commiſſary of artillery and ſome clerks of ſtores ſhould be likewiſe ſent to take account of all iſſues. The ſtores in each convoy ought to be claſſed under the proper head, that every thing may be kept diſtinct, and without confuſion: at the head of the line of artillery, ſhould be a waggon carrying a gin and hand jack, with proper ropes and tackles, in caſe any of the guns are overſet; the guns ſhould follow next on the block carriages, and then their carriages, ſtores, &c. in the order laid down in the inventory.

The drivers are divided into companies from 40 to 60 each, under the direction of a conductor, who has the charge of the carts, and is reſponſible that the drivers are attentive to their duty.

39 The detachment from the royal regiment of artillery, intended for the ſervice of the ſiege, is alſo divided in as many detachments as there are convoys, and the command of each is given to the eldeſt officer; who previous to the march, gives the neceſſary directions to his ſubalterns. When there are guns in the convoy, he poſts the moſt experienced non-commiſſioned officers and gunners on the flanks, to direct the drivers in the turnings and hollows of the roads, that the carriages may not be overſet through their unſkilfulneſs or negligence; a ſubaltern officer ſuperintends this particular duty: another ſubaltern and a party is detached to the powder; and the remainder is divided into three parts; of which one forms the vanguard, the ſecond the rear-guard, and the third is diſtributed in a ſingle file from front to rear, to prevent the line of march from being broken. A non-commiſſioned officer and ſome privates ſhould be ſent forward, to extinguiſh all fires in the houſes on the ſide of the road. If the number of artillery-men be inadequate to theſe duties, the commanding officer ſhould apply for a detachment of infantry. Matters being thus adjuſted, the drummers at break of day beat the *general*; and an hour afterwards the *aſſembly*, when the drivers harneſs their oxen; and at the third ſignal, the convoy moves in the order before-mentioned. At the

firſt ſignal, the quarter-maſter with the camp-colour-men and a waggon-maſter, goes forward to the place where it is intended to halt, in order to prepare quarters and forage, and chooſe a ſpot for parking the artillery; it ought to contain all the carriages drawn up in a ſquare, leaving between each file a ſpace ſufficient for harneſſing and unharneſſing the oxen. The park is formed as faſt as the carriages arrive; and guards poſted for the ſafety of the powder and ſtores, and to prevent the deſertion of the drivers. The forage is diſtributed in ſuch proportions, that the cattle may be able to continue their route at the appointed time. The guards furniſh rounds and patroles during the night, and allow no perſon to approach the park, unleſs ſent by the commanding officer. The ſame order of march is reſumed the next and following days, till the convoy reaches its deſtination; never moving more than 14 miles a day, eſpecially with oxen. To prevent confuſion, the drivers are obliged to keep the ſame place during the whole march; and for the ſake of puniſhing irregularity, each carriage is numbered, and the driver wears a ticket in his hat.

40. When part of the ſtores are carried on beaſts of burthen (23), in making up the ſeveral convoys, they ſhould be kept totally diſtinct from the carriages; and the officer who goes forward to mark out the park, ſhould pitch on one or two houſes for lodging the ſtores, where they may be ranged in their ſeveral claſſes, and the powder and other articles effectually ſheltered from rain. If no ſhelter can be found, ſome mules laden with planks and ſleepers ſhould march at the head of the convoy, to make platforms for keeping the articles that may be damaged by wet, from touching the ground; and oil-cloths with which every mule ought to be provided, ſhould be laid over the whole.

41. When the artillery and its appurtenances are to be tranſported in boats, ſome ſkids ſhould be laid under the guns and mortars, and ſmall floors made of planks for ſupporting the ſhot, ſhells, match, &c. always leaving a clear ſpace in the middle of the boat for bailing.

The ſtores are tranſported in waggons from the magazines to the place of embarkation, which ſhould be ſpacious enough to admit of many men being employed at the ſame time, without confuſion or danger of mixing the ſtores of different ſpecies together.

When

When there is a ſufficient number of boats, the whole ſhould ſet off at once, and form but one convoy; but when from the ſcarcity of boats, ſeveral trips muſt be made, the preceding directions for land-carriage ſhould be attended to, and a detachment of artillery ſent with each convoy, reinforced, if neceſſary, by a party of infantry: a particular guard compoſed ſolely of artillery-men, ſhould be put on board the powder-boats, which in the evenings ſhould be moored at a diſtance from the others. The place of debarkation having been pointed out by the commander in chief, to the officer who was ſent forward to the camp (33) the carriages which that officer has provided are ready to receive the guns and ſtores when the boats arrive, and tranſport them to the park. The landing-place ought to be ſpacious and commodious, and a working party of infantry without arms ſhould aſſiſt in unloading the boats.

42. It is taken for granted, that the country, through which the convoy is to paſs, is entirely clear of the enemy's troops; ſo that the guard will only have to prevent emiſſaries or marauders from pillaging or privately ſetting fire to the ſtores, or endeavouring in any other method to deſtroy them or impede the march.

But if the country be infeſted with flying parties of the enemy, it will be neceſſary to take other precautions with regard to the march and halts of the convoys; according as the danger ſeems more or leſs preſſing. The train of carriages, &c. ſhould be drawn up if poſſible in ſome ſecure place, as a walled town. In caſe of parking in the open country, a ſtrong ſpot ſhould be pitched on, and the acceſſible points fortified with palliſadoes or abbatis.

43. The neceſſary diſpoſitions to be made in marching through a ſuſpected country, may be reduced to the following caſes: when there is apprehenſion from flying parties only, detachments to check their incurſions are poſted in the towns and places contiguous to the route of the convoy, and a ſufficient eſcort marches with it for its protection.

When the convoy is expoſed to be attacked by a conſiderable body of troops, there are three methods of covering it: the firſt, by marching a corps ſuperior in number to the enemy, between them and the convoy, till it reaches the camp; this ſuppoſes but one convoy: if there be ſeveral, this corps muſt advance to the enemy, follow their motions,

and keep them in check, till the whole have paſſed. When the line of march can be covered by a large river, this route ſhould be preferred, though it may be the longeſt. The third method is when the eſcort that marches with the convoy is ſtrong enough to repel any attack of the enemy: the artillery ſhould in this caſe contribute towards it's own defence; it is neceſſary therefore to enlarge a little on this head.

44. In open champaign countries, the van and rear guards conſiſt of cavalry; the infantry, which is the main part of the eſcort, forms the centre. But in a ſtrong country interſected by rivers or canals, by foreſts, moraſſes, ravines, or defiles, the number of infantry is increaſed, and the cavalry diminiſhed, by ſubſtituting in their place dragoons, who occaſionally act as cavalry or infantry. If the route lie through a mountainous country, the eſcort is compoſed ſolely of infantry.

The command of a numerous eſcort is generally given to a general officer, who makes the following diſpoſition previous to the march, that every perſon may know their poſts in caſe of attack: a few hours before the convoy ſets out, he ſends detachments to reconnoitre the country, and divides his troops into four parts; the firſt forms the van-guard, the ſecond the rear-guard, and the third, which is the largeſt, and conſiſts ſolely of infantry, is reſerved for the centre: the fourth part is diſtributed in ſmall detachments along the flanks, to ſeize poſts and occupy croſs roads, &c. till relieved by the rear-guard. When the road is 25 feet wide, the carriages move two a breaſt, to ſhorten the line of march, and be the more ready to repel an attack.

Previous to croſſing a bridge, or entering a defile, the country on the other ſide ſhould be reconnoitered for fear of an ambuſcade, and the carriages drawn up in ſeveral lines cloſe to the bridge, that the eſcort may be as much as poſſible collected together: on moving forward, the former order of the march is reſumed. If during the march an order be given to prepare for action, the officer of artillery will inſtantly form the carriages into an oval or oblong figure, preſenting the longeſt ſide to the enemy, with the heads of the horſes or oxen turned toward the centre, that there may be no poſſibility of their running away: the infantry may be ſometimes compelled to retire behind the line of carriages, the powder waggons therefore for fear of accidents

accident ſhould be placed in the centre. But when from the nature of the ground, it is impoſſible to form in this manner, the carriages ſhould be drawn up in two or more lines, that the infantry may retire behind them, always placing the powder waggons at a diſtance. The guns mounted on travelling carriages ſhould be placed in ſituations, where from the nature of the ground, and the diſpoſitions of the enemy, their fire may have the greateſt effect. When the convoy conſiſts of beaſts of burthen, they ſhould be drawn up cloſe to each other, and in one line, that the infantry may from behind them as a parapet, direct their fire againſt the enemy.

Strict orders ſhould be given to the drivers under the ſevereſt penalties not to unharneſs before they are ordered; which can only be, when the eſcort is obliged to abandon the convoy: the artillery-men ſhould in that caſe, before they retire, privately diſpoſe ſome fire that it may communicate to, and blow up the powder and ſtores, ſo ſoon as the eſcort is out of danger.

## CHAP. III.

### Of the Park of Artillery.

45. THE park of artillery ſhould be eſtabliſhed in a ſecure place out of the reach of cannon-ſhot from the town, and as near as poſſible to the front attacked: it ſhould be ſo ſpacious that the different ſtores may be ſeparately claſſed, and loaded or unloaded without delay or confuſion. With theſe requiſites it is indifferent whether its figure be regular or not.

The carpenters, miners, and ſmiths ſhops are fixed in the houſes contiguous to the park; when there are no convenient houſes, ſheds are made of planks covered with oil-cloths. A large houſe at a proper diſtance from the park is choſen for the laboratory; and ſome detached buildings ſurrounded with walls and hedges for lodging the powder.

46. The waggons ſhould be unloaded as faſt as they arrive at the park, and ſent back; reſerving a proper number for tranſporting the guns and ſtores to the batteries.

The guns are drawn up in one or two lines; the 32 prs. mounted on their carriages; and the whole furniſhed with ſide-arms, coins, hand-ſpikes, and limbers, to be ready for ſervice. The mortars are left upon the block waggons; and the ſhot of different diameters ſeparated from each other. The intrenching tools are depoſited at the park; the artificer's tools ſent to the reſpective work ſhops; and the laboratory ſtores to the laboratory; the powder is lodged in the buildings allotted for it; a ſpace is left for the waggons that are to remain; and the tents of the artillery-men are pitched where they can beſt guard the park.

During the night a patrole goes conſtantly round the park and laboratory, to keep off pillagers or ſcouts of the enemy, and guard againſt fire; ſuffering no ſtranger or idle perſon to approach. A ſtrong guard is ſtationed over the powder magazine, allowing none to come near it but thoſe who are known to have buſineſs. All theſe guards ſhould be furniſhed by the infantry, that the artillery-men may not be diverted from other neceſſary duties.

47. Things being thus diſpoſed, the artificers are ſet to work; the carpenters to prepare timber for conſtructing bridges over the ditches, and laying the platforms of the batteries: the miners to make ready the frames for the deſcent into the ditch, and the attack of the countermines; and the ſmiths to repair any of the iron work that may have been damaged.

The ſenior officer of the bombardiers ſuperintends the laboratory. All the combuſtible articles are lodged, the compoſitions mixed, and the fuſes driven in the rooms leaſt expoſed to accident; and the ſhells and grenades are loaded under a ſhed ſeparated from the other buildings. Three or four ſmall furnaces are erected in convenient places for melting the pitch and glue.

The working hours are regulated, and the greateſt honeſty and ſobriety recommended. The floors of the rooms where the fuſes are driven, and the compoſitions mixed, are covered with oil-cloths: all iron tools are forbid to be uſed; no perſon is ſuffered to bring in fire of any kind, nor are any of the people employed at the furnaces allowed to enter the houſe: the loaded ſhells are put by themſelves. The bombardiers ſhould reject all ſplit or rotten fuſes, leſt the ſhells burſt immediately on being fired; they ſhould be careful not to make them too thin, leſt they ſplit in driving;

driving; and to cut them of a proper length: for, when they touch the bottom of the ſhell, the head being too long, may ſtrike againſt the mortar when fired, and break off, ſo that the ſhell will not burſt. The ſhells ſhould be examined before they are loaded, and thoſe rejected that do not ſtand the water proof.

The faſcines ſhould not exceed 10 feet in length; thoſe of 20 feet are only uſed when the works are intended to ſtand a long time; as they are more ſolid than works made with ſhorter ones.

## CHAP. IV.

### Of the Construction of the first Batteries.

48. THE object of the beſieger, in the conſtruction of his firſt batteries, is to diſmount the cannon in the front attacked, deſtroy the embrazures, and harraſs the garriſon ſo much in the ſeveral points of defence, that they may be obliged to abandon them, or at leaſt ſlacken their fire; that the approaches may be carried on with more expedition and leſs danger: 32 and 16 prs. are uſed for this purpoſe; the batteries are conſtructed with embrazures, and ſituated ſo as to fire *directly* againſt the works: the edifices in the town are likewiſe cannonaded from theſe batteries (19). The beſieged are perpetually harraſſed along the front attacked, with ſhot and ſhells fired *à richochet*; the batteries for this purpoſe are made without embrazures, on the faces of the attacked works produced; whence they are enfiladed with great preciſion and effect.

49. There are three kinds of batteries with embrazures; ſunk, level, or raiſed on cavaliers: the firſt require fewer workmen, and are ſooneſt made, wherefore they are always preferred when the ground permits: thoſe on cavaliers are never erected but through neceſſity, their conſtruction being very tedious and laborious.

(Pl. 1.) If the ground at the points G, H, K, be ſome feet higher than at P, Q, the batteries erected at G, H, K, may be ſunk. If G, H, K, and P, Q, be on the ſame level, the batteries may be likewiſe level; and when the ground at P, Q is higher than at G, H, K, ſo that the ſap cannot be carried on without the ſappers being endangered by the

fire from the batteries G, H, K, then they muſt be raiſed on cavaliers. Mortars and richochet batteries ſhould be always ſunk; they may be made in the approaches, which will ſave time; and they will be leſs expoſed to any attempts of the enemy. The mortar batteries, L, N, Q, and the richochet batteries M, O, are ſunk in the parallels. Batteries for red-hot ſhot may alſo be ſunk in ſome part of the trenches. It having been demonſtrated in the treatiſe on projectiles, that the path of a projectile is always a curved line, whatever be its initial velocity, or length of range, it is evident that the direct fire mentioned above, can only be relatively reputed ſuch in practice: for, to expreſs in few words the difference between two lines of projection, one of which is *direct*, or, more accurately ſpeaking, the curvature of which is but ſmall, and of the other, large; if we ſuppoſe the beſieged to be covered by the parapets from the former, they will be expoſed to the latter.

50. The object of the firſt batteries being to diſmount the artillery that may impede the progreſs of the ſap (17, 48); the fire from them ſhould be nearly perpendicular to the faces of the works attacked, and at a proper diſtance; that is to ſay, from 400 to 550 yards from the covered way: when at a greater diſtance, the ſhot will often be of no effect; and when nearer, they will be too much expoſed to the muſquetry of the place. Upon this principle, it ſometimes happens that two batteries are joined together, and preſent a ſaliant or re entering angle towards the place; and at other times are entirely ſeparate: this difference proceeds ſolely from the diſtance between the battery and place, and the relative ſituation of the works.

(Pl. 1.) In this caſe, there are but three batteries with embrazures, viz. G, H, K; each of which has two faces preſenting a ſaliant angle towards the place.

If theſe batteries were erected at the points R nearer to the place, the faces would be ſeparated, and there would be ſix ſingle batteries R: again, if they were erected at S, farther diſtant than G, H, K, there would be three batteries, each preſenting a re-entering angle towards the place; and if carried farther back as to T, there would again be ſix ſingle batteries.

If, inſtead of varying the diſtances of the batteries from the place, we ſuppoſe a difference in the relative poſition of the works, the batteries in order that their fire may be

perpendicular

perpendicular to the faces of the works, muſt be erected more to the right or left, which will occaſion ſimilar changes in their figure and ſituation.

Some artilleriſts having obſerved that the batteries S, T eſtabliſh a croſs fire, concluded that they were preferable to batteries G, H, K, the fire from which does not croſs; but to deſtroy ſo erroneous an opinion, it is ſufficient to recollect that a croſs fire is only advantageous when the point of interſection falls on the object to be battered, when being thus taken in front and flank, the effect is greater. The lines of direction G A, L A, are preciſely of this kind, as they batter in front, and enfilade at the ſame time the face A; whereas in the croſs fire X A, X B, though the lines of direction interſect each other at the point Y, yet their effect upon the faces A, B, is the ſame as if they did not interſect each other, and were drawn from the battery G.

By help of the directions given in this and the firſt chapter, it will be eaſy in every caſe to determine the number, ſituation, direction, and kind of batteries moſt proper for battering the works, demoliſhing the buildings, breaking through caſemates not conſtructed with ſufficient ſolidity, and cannonading with red-hot ſhot; it only remains then to point out the method of conſtruction.

51. In regular ſieges, batteries are conſtructed with faſcines and pickets to give them the requiſite ſolidity.

So ſoon as the engineers have carried on the approaches to the places where the firſt batteries are to be erected, the commanding officer of artillery makes a diſpoſition of his officers: he detaches a captain to each of the moſt conſiderable batteries as G, H, K, and puts under his direction a competent number of ſubalterns, non-commiſſioned officers and gunners; he then accompanies the eldeſt of the captains to the ſpot where the battery is to be erected, and traces it out with pickets, leaving an interval of 20 feet between every two guns; he does the ſame at the other batteries in ſucceſſion. The captain of the firſt traced battery returns to the magazine, where all the artillery men and parties of the line that are to work at the conſtruction of the batteries during the night, aſſemble before ſunſet. The adjutant of artillery makes the diſtribution of pioneers, in proportion to the extent and kind of battery, allotting 14 or 16 men to every 20 feet in length, when the battery is to be with embrazures, and ſunk; and 20, or 25 when it is to be raiſed, the exact number of men being determined by the

the diſtance from the park. At ſunſet, the captain takes the major part of the ſubalterns, and a few men to carry faſcines, pickets, and mallets, and marks out the battery; making his detachment obſerve the roads and turnings, that the men who bring up the ſtores may not miſtake the way; which frequently happens when this precaution is neglected, particularly if the road does not run along the trenches of communication, but acroſs fields and meadows. While the captain is thus employed, the ſubalterns and a part of the non-commiſſioned officers return to the park: the pioneers are by this time divided into ſquads, and provided with ſhovels and pick-axes alternately; they then load themſelves with faſcines and pickets, and each ſquad with an officer in front, and a non-commiſſioned officer in rear, proceeds with all expedition to the battery; a ſerjeant marching on the flank to make the men keep their files, and prevent the line from being broken, or any unneceſſary delay. When the ſquads arrive at the battery, their work is pointed out; one or two being reſerved to tranſport the reſt of the materials from the park to the battery.

52. In ſunk batteries, the interior face is traced parallel to the exterior at 20 feet diſtant; and on both faces, pickets are planted at every 20 feet to mark the centre and direction of each embrazure. On the interior face, 12 inches are ſet off to the right, and as many to the left of each picket; and on the exterior face $4\frac{1}{2}$ feet to the right, and as many to the left, which gives the form of the merlon. A trench is then dug on the interior face $2\frac{1}{2}$ feet deep, and lined with faſcines picketed to the ground: to give the battery greater ſolidity, a ſtratum or layer of long pickets is placed with the heads reſting on the upper faſcines; theſe heads which are about 6 inches in diameter form part of the interior revetement: the remainder of the merlon is traced with faſcines picketed to the ground.

The ditch is then enlarged towards the country, and the earth thrown into the merlons: in proportion as they are raiſed, other faſcines are placed, and a layer of long pickets laid between every two rows of faſcines along the ſides of the embrazures, and between every three rows along the interior and exterior faces; the ſlope on both faces is a fourth part of the height. In general, the merlons are not raiſed above three feet the firſt night. At day break the workmen are relieved by a freſh working party, and the ground levelled, that the carpenters may lay the platforms. At ſunſet a freſh party

completes

completes the battery, conſtructs the powder magazines, and mounts the guns on the platforms as faſt as they arrive, that the battery may be ready to open at break of day. While the batteries are erecting, a part of the line make two trenches of communication between the flanks of the battery and the neareſt parallel; this detachment is likewiſe relieved every 12 hours.

53. In level batteries, the figure is firſt marked out with faſcines picketed to the ground, and not leſs than 20 feet allowed for its thickneſs when the ſoil is firm and tenacious, and 25 feet when it is light or ſandy; leaving a berm 5 or 6 feet wide on the exterior ſide. The workmen then begin to dig the ditch, throwing up the earth to raiſe the battery; upon the ſecond faſcine, on the exterior face is placed a layer of long pickets, and on the interior face another row of faſcines, which gives the height of the cell of the embrazure. The ditch inſtead of being widened ſhould be deepened as much as poſſible the firſt night, that the pioneers may the next day work under cover. The battery is ſeldom raiſed above 2½ feet high the firſt night: the merlons are traced in the manner before directed. At break of day this working party is relieved by another conſiſting of half their number; they enlarge the ditch all the day, throwing up the earth to form the battery or merlons, if traced. When the embrazures have not been marked out, the ſenior officer plants the pickets at ſun-ſet for determining their direction, and completes the tracing of the merlons at the arrival of the freſh working party, which ſhould be as numerous as in the preceding night; for the ſake of diſpatch, a proportion of work is allotted to each man, that the battery may if poſſible be finiſhed that night, which however rarely happens when the nights are ſhort. During this night alſo the platforms are laid, and ſome guns brought to the battery, if they be covered from the enemy's fire during the next day. The following day and night are employed in conſtructing the powder magazines, completing the batteries, and preparing every thing for opening them on the third morning at ſun riſe. During the firſt night alſo, the communications between the flanks of the batteries, and the neareſt parallel are made, that in caſe of a ſally from the town, every part of the trenches may be mutually ſupported.

54. In conſtructing batteries on cavaliers, the firſt ſtep is to raiſe the ground to the ſame height as the intermediate ground

ground between the battery and the place. Too many pioneers cannot be employed in this work during the night; but during the day ſo many only as can be covered from the enemy's fire; and to expedite the work, the ſoil neareſt at hand is uſed. The breadth at top ſhould be at leaſt 45 feet, and the ſlope two thirds of the height. A berm of 5 feet is left towards the place, and the dimenſions of the battery are the ſame as before directed (53). In the rear of the battery a proper ſlope is made for the drawing up the cannon, and adjoining to it is conſtructed the powder magazine.

The battery for ſchool-practice on the other ſide of the river Po will convey a juſt idea of this ſpecies of battery, and be at the ſame time a convincing proof that works which require ſo much time and labour, ſhould never be undertaken at a ſiege, without an abſolute neceſſity.

It has been advanced by ſome authors, that the firſt batteries ſhould always be erected on cavaliers, even if the ground be on the ſame plane with the place, that greater part of the ramparts may be thereby diſcovered: but if we reflect how high the cavalier muſt be raiſed before a ſingle foot of the revetement can be ſeen, it will appear that ſuch a trifling advantage by no means compenſates for the loſs of time and labour; beſides, as the firſt batteries are intended to diſmount the artillery of the place, and deſtroy the defences, this end will be fully anſwered when the beſieger from them can ſee his objects without endangering the lives of the ſappers, or interrupting their progreſs.

55. So ſoon as the ſecond parallel is completed, the firſt richochet and mortar batteries are conſtructed at the points whence the faces of the covered way, and the attacked works can be enfiladed with moſt effect (17). Theſe batteries ſhould be completed in twenty-four hours; wherefore, 14 or 16 pioneers are allotted to every 20 feet; the parapet is faced with faſcines, and the trench enlarged as much as may be neceſſary: paſſages of communication are made round the rear, to prevent any embarraſſment; and the powder magazine is conſtructed in the ſpace between this communication and the battery. When the richochet batteries can be incommoded by a plunging fire from the cannon of the ramparts, embrazures ſhould be made from 6 to 8 feet wide, ſloping inwards: by this expedient the guns will be concealed, and may be placed cloſer to the parapets. When the ſappers begin the third parallel, the

fire

fire from the richochet batteries ceaſes; ſome royal mortars are then placed in the ſecond parallel to annoy the troops in the covered way; and for the ſame purpoſe, ſome ſtone mortars are brought into the third parallel, ſo ſoon as any part of it be finiſhed. The batteries for theſe pieces need not be faced with faſcines, unleſs the ſoil be ſandy; it being ſufficient if they reſiſt the ſhock of the diſcharge.

56. The guns and mortars are drawn to the batteries during the night, along the roads leaſt expoſed to the enemy's fire: proper bridges having been previouſly laid over the trenches for their paſſage: the horſes ſhould be changed where the ground is level, and any that are killed or wounded immediately unharneſſed.

If the road be expoſed to the fire of the enemy's muſquetry, two or three guns only ſhould be brought forward at a time, to avoid the confuſion that ariſes when any of the horſes or drivers take fright. In mountainous ſituations, where the muſquetry of the place has a great command, new roads for the cannon ſhould if poſſible be made leſs ſteep and expoſed. In ſteep and winding roads that cannot be made practicable for horſes, the guns muſt be dragged by men: when this muſt be performed under the fire of the place, ſtrict ſilence and regularity ſhould be obſerved, and the whole halt and move forwards at once, by ſignal from the commanding officer.

## CHAP. V.

### Of the Daily Service of the first Batteries.

57. THE batteries being compleated, the general of the trenches for the day gives an order for them to open; and immediately each battery directs its fire againſt its particular object.

The richochet and mortar firing is continued, but the direct firing ceaſes during the night. By uſing moderate charges, loading the guns with care, and pointing them with accuracy, the ſervice will be carried on with preciſion and effect: for when the guns in the firſt batteries are fired with the charges that produce the longeſt ranges, the object

is

is frequently miſſed from the violent ſhock that the carriage ſuſtains, a great quantity of ammunition is uſeleſsly expended, and the guns are often rendered unſerviceable, before the concluſion of the ſiege.

58. In making the diſtribution of artillery-men, the following is the proportion to be relieved every 24 hours; *viz.* eight men to a 32 pr. ſix to a 16 pr. 13 inch or ſtone mortar; four to an 8 pr. and 10 inch mortar; and two to a royal mortar. An officer and non-commiſſioned officer are attached to every 4 or 6 pieces; and when a battery contains a greater number, it is commanded by a captain.

59. The object of the direct firing is to diſmount the artillery and ruin the defences, that the garriſon may be unable to work their guns when the beſieger has eſtabliſhed himſelf with his muſquetry in the ſecond or third parallels. The firing from any battery ſhould never be diverted from the particular object againſt which it is intended to any other, as ſuch deſultory operations are generally inefficacious towards the reduction of the place. The common rate of firing from batteries at a ſiege is at moſt 9 rounds an hour from each gun.

In richochet firing, the guns are elevated between 8° and 12°; and fired with very ſmall charges, juſt ſufficient to throw the ſhot over the parapet or into the covered-way; that it may afterwards make ſeveral bounds: the proper charge having been aſcertained, is put into flannel cartridges; that the powder being always collected together in the ſame manner the inflammation may be uniform; and ſince the firing is to be continued day and night, the coins and platforms ſhould be marked that the elevation and direction may remain the ſame.

In batteries for throwing red-hot ſhot, a large iron grate is fixed behind the battery; the ſhot are laid in it and a ſtrong fire kindled: the proper charge for throwing the ſhot into the place with an elevation from 8 to 12° is put into the gun with a wad and turf over it; then the gun being pointed and primed, a gunner ſponges it out with a wet ſponge, and with a pair of pincers puts the red-hot ſhot into the gun, and another gunner inſtantly ſets fire to the priming with a match. Theſe batteries likewiſe fire night and day; but as the guns are ſoon heated, the firing ceaſes at proper intervals to allow them time to cool.

60. The mortars intended to enfilade the works in order to diſmount

diſmount the artillery and harraſs the beſieged, ſhould be laid at ſmall elevations, that the ſhells may not bury themſelves: and when from the ſmall extent of the work to be enfiladed, this method would produce no effect; the charges ſhould be diminiſhed and the elevation fixed between 35° and 45°, being that, as has been already obſerved, which is leaſt liable to irregularity. Mortars deſigned for breaking through caſemates ſhould be fired at the higheſt elevation and with the largeſt charges, that the ſhells may produce the greateſt effect, ſuppoſing they fall on a horizontal plane: but if it be inclined, the charge muſt be ſo combined with the elevation as to cauſe the greateſt poſſible ſhock. The ſolution of this problem may be found in the eſſay on projectiles. Seldom more than 5 rounds from each mortar can be fired within the hour, from the very great attention neceſſary in loading and laying them. The ſchool practice will ſhew the ſervice of ſtone mortars at ſieges; the ſhowers of ſtones projected from them produce great effect when fired at an elevation between 40° and 50°, and with a range not exceeding 270 yards.

61. In caſe of a general ſally of the garriſon, the officers will direct as heavy a fire as poſſible from the batteries againſt them, bring ſome of the guns to the flanks of the battery to cover the adjoining parallel; and uſe round or caſe-ſhot according to circumſtances. There are frequently ſome field pieces placed on the flanks of the places of arms for checking ſorties. If, in ſpite of theſe diſpoſitions, the guard of the trenches is overpowered, and the enemy are on the point of getting poſſeſſion of the batteries; the artillery men ſhould diſcharge all the guns, and carry the ſide-arms into the parallel in the rear, leſt the enemy turn the guns upon them. But theſe enterprizes cannot be of long duration, for as ſoon as the beſiegers advance in force, the garriſon will be compelled to retire; the artillery-men ſhould then inſtantly return to their batteries; and in the firſt place examine the magazines to ſee that the enemy have not concealed any fire in them; they ſhould then recommence their fire againſt the troops of the ſortie, and when the action is over repair any damage that may have been done to the battery.

62. The commanding officer of artillery will viſit the batteries every morning to ſee that the fire be well directed, and examine the effects of the preceding day: he will then go and make his report to the commander in chief of every thing within his department, and ſubmit to him his ideas on

the

the future conduct of the ſiege: he will viſit the batteries again in the afternoon, taking with him a ſtaff officer; to take notes of what ammunition will be wanting for the current ſervice of the following day, and what caſe-ſhot and flannel cartridges, to enable the batteries to keep up a very cloſe fire in caſe of ſallies: he will alſo examine whether the magazines of the centre and flanks of the ſecond parallel be provided with cartridges and flints for the infantry. On his return to the park, he will direct the articles that are to be ſent to each battery to be ſeparately prepared; and delivered over to the non-commiſſioned officers and privates detached in the evening to receive and conduct them at cloſe of day, along the roads that lead moſt directly from the park to their reſpective batteries.

## CHAP. VI.

### Of the Second and Third Batteries.

63. IT being the object of the ſecond batteries to make practicable breaches in the works, they ſhould be combined two and two together in ſuch a manner, that while one batters in breach the other may play on the defences that cover the breach. The ſecond mortar-batteries will be properly diſpoſed, if while one bombards the work that the beſieger intends to give the aſſault to, and prevents the garriſon from throwing up intrenchments within it, or at leaſt retards their conſtruction; the other directs its fire againſt the works that defend the breach: ſo that the garriſon may from the continual ſhower of ſhells be compelled to abandon the defences; or, if they perſiſt in remaining, be expoſed to great loſs.

64. When the trenches are advanced under the fire of the firſt batteries far enough to eſtabliſh the batteries in breach, the artillery-men will conſtruct them on the points whence their fire may the moſt ſpeedily and effectually render the breaches practicable.

If the profiles of the works be advantageous for defence, and there be no commanding points, the batteries in breach and the collateral batteries muſt be erected on the creſt of the glacis; but if there be a riſing ground, whence at leaſt half of the circuit of the place can be ſeen, and any points nearer

to

to but lower than the works, whence they can be battered with effect, as in the case of the place being built on an eminence and much exposed; then the batteries in breach should be erected on these points and collateral batteries established to destroy the defences.

Each battery should be erected opposite to that part of the fortification which it is intended to batter; and the breach will sooner be rendered practicable, if some guns can be brought to bear upon it obliquely. The service of the mortars will be most exact, when their batteries are perpendicular to the faces produced of the works that are to be bombarded; those for the stone-mortars should be established in the most advanced lodgements, taking care that the stones from their spreading can do no injury to the besiegers.

65. The third batteries are constructed on the outworks of the place: when there are two lines of out-works, the besieger after reducing the first, must erect a fourth set of batteries in the outworks most contiguous to the body of the place; he will also be under the necessity of doing this, whenever the body of the place is constructed on a *system of demolition*, or with double bastions: he must determine on the spot from actual observation, whether there be any readier or surer method of reducing them than by opening breaches.

66. In the second plate these directions (63, 64) are exemplified: the battery in breach A is opposite to the part M M of the face of the ravelin in which a breach is to be made, and some guns might if necessary be placed at I to bear on it obliquely; the collateral battery B is directly opposite to the part Q that flanks the face M M. The battery in breach C is opposite to the part N N of the face of the bastion in which a breach is to be made, and if the ground at C does not admit of a sufficient number of guns, two or three may be planted on the face O of the place of arms, or on the lodgement made by the sappers within it; these two batteries will be supported by the collateral battery D opposed to the flank R.

The face M M of the ravelin and the flank R are enfiladed from the mortar battery G; and some stone-mortars are placed at F and E, to project stones into the flank R and the ravelin P, and interrupt the communication between the ravelin and the body of the place. The mortar battery K enfilades the ravelin and its communication, and contributes to annoy the flank R, and the part Q that covers the breach

M M: finally, the mortar battery H enfilades the face N Q, as well as the interior of the baſtion.

If there be a cavalier, tenaille or fauſſe-braie, ſo as to make R a double flank, the number of mortars ſhould be increaſed.

All the diſpoſitions here laid down for attacking the body of a place, are equal applicable to the attack of a more extended front, whether covered with horn or crown-works.

67. With counter-guards before the baſtions and ravelins, the batteries in breach ſhould be conſtructed in ſuch a manner that after the counter-guards are reduced, the guns may bear on the works they covered, in caſe the profiles of the counter-guards are too narrow to admit of the third batteries being erected on them. Thus, batteries ſhould be erected at A, B (Pl. 3.) to open a breach at C C correſponding to the part K K of the face of the ravelin; and other batteries at D, E to open a breach at F F correſponding to the part L L of the face of the baſtion. The collateral batteries ſhould be erected agreeable to the preceding maxims; one at G to bear upon the flanking part I; and another at H to bear upon M. When the beſieger after getting poſſeſſion of the counter-guards, finds himſelf under the neceſſity of conſtructing a battery at N to ruin the defences O of the breach K K and another at P to ruin the defences Q of the breach L L, and the counter-guards are ſo narrow that the guns cannot be brought up through the breaches C C, F F to the reſpective batteries N, F; he muſt conſtruct four others on the creſt of the glacis; *viz.* one at R to make a breach at N where the guns may be got up, and a collateral battery at S to ruin the defences T; a third at V to make a breach at P in order to get up the guns; and a collateral battery at X to ruin the defences at Z. Under this ſuppoſition, the number of guns for batteries on the creſt of the glacis, will far exceed the number requiſite for the firſt batteries; which muſt be allowed for in making up the proportion of ſtores (28).

The rules given for the mortar batteries will be equally applicable to this as the preceding caſe (64), and will give the ſame poſition Y.

68. The batteries conſtructed on the creſt of the glacis are always ſunk, ſince the lodgements made there form a parapet. It ſhould never be leſs than 20 feet thick; and for greater ſolidity the interior part ſhould be faced with faſcines. The diſtance between every two guns is 20 feet, independent

of

of the traverſes of which there ſhould be ſeveral to prevent the batteries being enfiladed. The interior width of the embrazures ſhould not exceed 20 inches, that the gunners may be ſheltered as much as poſſible from the muſquetry of the place; without this precaution the ſervice will be much retarded.

If the place be ſo ſituated that it can be battered in breach from any of the adjacent points, batteries ſhould be erected on them without regarding the lodgments on the glacis; theſe batteries may be either ſunk or raiſed according to the nature of the ground.

The artillery-men being very much expoſed to the enemy's muſquetry during the conſtruction of the ſecond batteries, the general of the trenches ſhould order a number of markſmen to be ſtationed at proper places behind ſand-bags or gabions, to keep up a continual fire on the parts whence the artillery-men are moſt annoyed. While the batteries are erecting, the commanding officer of artillery gives the neceſſary orders for moving the guns towards them, cauſing proper bridges to be laid over the trenches for this purpoſe.

If there be a dry ditch in the way, a ſlope may be made for getting the guns acroſs; but if wet, a bridge muſt be thrown over. When the approach to the batteries is tolerably level, the guns may be drawn up by horſes one at a time, to prevent the confuſion that generally enſues when a gun is diſmounted or a driver killed: when the approach is narrow and ſteep, the guns muſt be dragged by men.

69. The batteries for making breaches ſhould fire day and night, directing their fire againſt the foot of the wall; and afterwards againſt the counterforts: ſince the earth ſoon crumbles down, when the counterforts that ſupport the wall are beat down. A wall not very thick and ſolid is ſooneſt demoliſhed with ſmall charges and an oblique direction: on the contrary, the charges that give the greateſt initial velocities ſhould be uſed againſt walls of great thickneſs, provided there be no danger of the guns becoming unſerviceable before the concluſion of the ſiege. It will be likewiſe proper to fire *ſalvoes*, i. e. to diſcharge all the guns together; as beſide the holes made by the ſhot, the adjoining parts are more violently ſhattered, even in the moſt ſolid revetements. The collateral batteries ſeldom fire during the night, their primary object being to diſmount the artillery of the place, and enlarge the embrazures ſo as to render it dangerous for the beſieged to

work their guns. When this ſervice is effectually performed, their fire is directed againſt the other parts of the parapet to deſtroy all ſhelter for the enemy, and the whole is ſeconded by a briſk fire of muſquetry from the beſiegers, that the artillery-men being covered may fire with greater juſtneſs and preciſion. The ſecond mortar-batteries will fire day and night according to the former directions (63, 64).

70. The third batteries are conſtructed in the lodgments made in the outworks, and the ſame precautions taken as during the conſtruction and ſervice of the ſecond batteries to cover the artillery-men from the fire of the place.

When there are no outworks but ravelins, and the enemy ſeem determined to defend the breach in the baſtion to the laſt extremity, ſome guns ſhould be brought, into the lodgment made in the gorge of the ravelin, to bear on the breach; or a mortar-battery conſtructed, to fire inceſſantly into the baſtion, to prevent the garriſon from throwing up intrenchments to protract the ſiege. Should the curtain be covered by a tenaille or other works, a battery muſt be conſtructed in the ravelin to fire againſt it.

When the baſtions are double, or conſtructed on a ſyſtem of demolition, and a lodgment is completed in the exterior baſtion between the ſummit of the breach and the ſecond baſtion; the beſieger muſt erect a third battery to demoliſh the interior work, when it can by this method be effected in leſs time than by mining.

FIG. III. Should the profiles of the counter-guards admit of it, the third batteries may be conſtructed at C C, F F, to open the breaches at K K, L L; and the collateral ones at N, P to ruin the defences: in this caſe, it may perhaps be neceſſary to erect the fourth battery in the ravelin or baſtion. But with narrow profiles, the parts C C, F F, muſt be battered from A, B, D, E, till they are ſo completely beat down that K K, L, L, can be battered in breach from A, B, D, E.

The beſieger having made himſelf maſter of a horn or crown-work ſhould erect the third batteries on the terre-plein, the interior ſlope, or the gorge, as may beſt anſwer his purpoſe; the mortar-batteries may be placed in the ditch before the front of the work.

The greateſt difficulty met with in completing the third and fourth batteries, particularly when conſtructed on the counter-

counter-guards is in getting up the 32 prs. which from the narrowneſs and ſteepneſs is a very troubleſome and tedious operation, ſince they muſt be dragged by men.

## CHAP. VII.

### Of the Attack of Countermines.

71. HITHERTO the beſieger has been ſuppoſed to conſtruct his batteries on the glacis and the other parts of the outworks, without any moleſtation from the countermines of the beſieged: but if the place be well countermined and under the direction of ſkilful officers, the eſtabliſhment of the batteries will be a very arduous undertaking; ſince in this ſubterraneous war the advantage lies on the ſide of the beſieged. That the ſecond and third batteries may be erected in proper ſituations, and the ſubſequent operations of the ſiege not retarded by the ſpringing of the countermines, one of the firſt objects of the beſieger is to render them of no effect; either by filling them with water by means of a canal made for that purpoſe; by rendering the air unfit for reſpiration, by throwing into them various compoſitions that emit an inſupportable ſtench and ſmoke of a fetid and poiſonous nature; by making a few fougaſſes to cut off the communications between them and the body of the place; by overſetting on the principle of compreſſion, the galleries and branches intended to blow up the batteries; or finally, by ſeizing poſſeſſion of the countermines along the front of the attack and preventing the beſieged from entering into them. But the beſieger not having it always in his option to adopt the moſt convenient method, even when provided with an exact plan of the countermines; and being, when he has no plan, under the neceſſity of feeling his way with extreme caution and at great hazard; here follows a general idea of each mode of attack, that the beſieger may judge which is beſt ſuited to the particular exigency.

72. When the level of the countermines is lower than the ditch, ſo that a ſtream of water may be made to flow into them, this expedient will be the moſt eaſy and effectual. To this end, the pioneers are employed in digging a proper canal; while the miners divided into ſquads are ſearching

for the principal galleries, either by ſinking ſhafts or making ſlopes in the glacis; and the inſtant they have diſcovered one, they make an opening to turn the water of the canal into it.

73. If the countermines cannot be inundated, the readieſt and leaſt dangerous way is to attack them at the entrance, which is known to be in the ſaliant and re-entering angles of the covered way, and deſtroy them: the beſieged will be then prevented from penetrating into thoſe under the glacis. To this end, the ſappers muſt effect a lodgment between the ſaliant angles of the covered way and the places of arms: when theſe lodgments are effected, the ſquads of miners muſt as expeditiouſly as poſſible ſink ſhafts a little lower than the countermines, from 40 to 60 feet diſtant from each other, and carry on two branches parallel to the counterſcarp and a return at the extremity of each to form the chambers; which muſt be well loaded, that the adjoining galleries and branches may be entirely overſet by the exploſion. If, in the courſe of this work, they meet with a gallery, they muſt immediately break into it, and throw in quantities of fetid compoſitions to make it impoſſible for the beſieged to re-enter, that that they may finiſh their mines without moleſtation; they ſhould be ſprung as ſoon as completed.

When the beſieged deſtroy any of the ſhafts by ſpringing a countermine, others ſhould be immediately ſunk at ſuch a diſtance from the former, as not to paſs through any of the earth ſhaken by the exploſion; ſince the labour of the miners in working among looſe earth is endleſs, for the ſides crumble down as faſt as the excavation is made.

Suppoſing theſe ſhafts to be completed and the chambers charged, other ſhafts may be ſunk in the lodgments on the creſt of the glacis, particularly on the capitals of the works, for the purpoſe of more eaſily exploring the enemy's galleries under the glacis and entering them, when the communication between them and the body of the place is cut off by ſpringing the mines under the covered way; and when by means of theſe ſhafts a gallery is diſcovered, a party of armed miners ſhould examine whether there be a poſſibility of the beſieged returning into it. If it be poſſible, they ſhould penetrate beyond the points correſponding to the attack, and throw in ſome fetid combuſtibles, taking care to retire time enough to ſave themſelves from ſuffocation; and then

then deſtroy the communication with tools, and afterwards with a chamber, which will effectually deprive the beſieged of all acceſs.

When there are two ſtages of countermines, and the miners in penetrating into the upper one, find the ventilators belonging to the lower ſtage; they ſhould throw in ſuch quantities of fetid combuſtibles as will render it impoſſible for the beſieged to remain in them, taking the precaution to cloſe the ventilators, that they may not be incommoded by the ſmell and ſmoke, which in theſe ſubteraneous operations are extremely pernicious.

74. It has hitherto been ſuppoſe that the ground around the place is nearly level: but when the fortreſs is built on a tongue of land, ſo that the front of the attack be terminated on each ſide by a deep ravine, the miners may then drive a ſhaft below the countermines, and thoſe parts of the outworks on which the batteries are to be erected; and make ſome chambers for blowing up the works, or at leaſt deſtroying the countermines: or, if the place be ſituated on an eminence, and the ſlope of the glacis ſuch that the miners can drive a ſhaft below the countermines and penetrate under the points where the ſecond batteries are to be erected, advantage ſhould be taken of theſe circumſtances.

It ſhould in general be underſtood, that whenever any ſubterraneous work of great extent is carrying on, a gallery muſt be made to give a free circulation of air; but in limited operations, a branch which is ſooner made will anſwer every purpoſe.

74. If the beſieged make no attempt to deſtroy the ſhafts in the covered way (73), it is a ſign either that they are ignorant of their duty, or are ſeized with diſmay; wherefore, if the miners meet with any of their galleries inſtead of empoiſoning them, they ſhould enter them and advance towards the doors that lead into the ditch; and ſupported by a ſecond detachment proceed into the large gallery on each ſide, till they have paſſed beyond the front of the attack, and deſtroyed the gallery in every part by which the beſieged can re-enter the countermines: when there are two ſtages, they ſhould endeavour to deſcend into the lower one, and approach the doors that lead immediately to the body of the place; this gallery ſhould alſo be deſtroyed with the greateſt expedition. Having thus taken poſſeſſion of the counter-

mines, they ſhould make fougaſſes to render all endeavours of the garriſon to regain poſſeſſion of them abortive.

76. The diſcuſſion of this ſubject has been hitherto confined to ſhafts, galleries, branches, and chambers made in firm and ſolid ground; but in a looſe ſandy ſoil, the excavation requires the addition of frames and planks, to ſupport the earth along the whole of the ſubterraneous work: and as theſe operations muſt be performed as expeditiouſly as poſſible that the beſieged may have the leſs time to deſtroy them by countermining, the ſquads of miners ſhould be relieved every ſix hours; ſince in that time each man will have had his turn of the moſt laborious part of the work. Shafts are generally made ſquare, and the dimenſions of the ſmalleſt are $4\frac{1}{4}$ feet. The galleries are 6 feet high, and about $3\frac{1}{4}$ feet wide. The branches $4\frac{1}{2}$ feet high and 3 feet wide; a return is made at the extremity of each branch for the chamber which is of a cubical form, and in it is placed a wooden box of the ſame figure to contain the proper quantity of powder; the ſpaces between the ſides of the chamber and the box are filled up with clay or dung. The ſauciſſon is laid in a pitched wooden trough; and the branch and adjoining ſhaft or gallery filled with bags of earth or ſand, and the angles barred with ſtrong oaken planks, ſupported by croſs beams, that the line of leaſt reſiſtance may be on the ſide againſt which the mine is intended to act.

77. The quantity of powder for charging mines, intended only to ſhake the ground without making any excavation, depends on the quality and tenacity of the ſoil, and on the line of leaſt reſiſtance: but it being ſometimes out of the power of the beſieger to make proper experiments for aſcertaining the tenacity; the following table will ſerve as a rule for the quantity to be uſed, in a ſoil of ſuch tenacity as to need no frames to ſupport it, in order to ſhake the ground from the bottom of the chamber to the ſurface, without diſplacing it; ſuppoſing the powder to be of a ſtrong quality and well preſerved.

Table

Table of the Quantity of Powder, for charging Mines under different Lines of leaſt Reſiſtance.

| Lines of leaſt Reſiſtance. | Interior ſide of the Chamber. | | Quantity of Powder for charging the Chamber. | | |
|---|---|---|---|---|---|
| *Feet.* | *Feet.* | *Inches.* | *Cwt.* | *qrs.* | *lbs.* |
| 10 | 1 | 2 | 0 | 3 | $18\frac{1}{2}$ |
| $13\frac{1}{3}$ | 1 | 7 | 2 | 0 | $1\frac{1}{2}$ |
| $16\frac{2}{3}$ | 2 | 1 | 3 | 3 | $10\frac{1}{2}$ |
| 20 | 2 | 4 | 6 | 2 | 10 |
| $23\frac{1}{3}$ | 2 | 9 | 10 | 2 | 13 |
| $26\frac{2}{3}$ | 3 | 2 | 15 | 2 | 27 |
| $30\frac{1}{3}$ | 3 | 6 | 22 | 2 | $1\frac{1}{2}$ |
| $33\frac{1}{3}$ | 3 | 11 | 30 | 1 | 16 |
| $36\frac{2}{3}$ | 4 | 4 | 41 | 0 | 0 |
| 40 | 4 | 9 | 53 | 1 | 22 |
| $43\frac{1}{3}$ | 5 | 1 | 67 | 3 | $17\frac{1}{2}$ |
| $46\frac{2}{3}$ | 5 | 6 | 84 | 2 | $27\frac{1}{2}$ |
| $49\frac{1}{3}$ | 5 | 11 | 104 | 1 | 9 |

78. In the uſe of this table, it ought to be obſerved that the object of the beſieger being to deſtroy the countermines effectually, his mines ſhould be fully charged; wherefore the quantity marked in the table ſhould be generally increaſed by a half: thus, if the line of each reſiſtance be 23 feet, the quantity of powder for the charge according to the table is $10\frac{1}{2}$ cwt., to which add $5\frac{1}{4}$ cwt. or the half; then $15\frac{1}{4}$ cwt. will be the charge required, to be contained in a cubical box of about 3 feet 2 inches on the interior ſide. If the tenacity of the ſoil be greater, the charge muſt be increaſed to double the quantity in the table; thus the line of leaſt reſiſtance being 26 feet, by doubling the quantity $15\frac{1}{2}$ cwt. marked in the table, 31 cwt. will be the charge required to be contained in a box 3 feet 11 inches on the interior ſide. In looſe ſandy ſoils, the ſame rule muſt be obſerved; as the elaſtic fluid eſcaping more eaſily, acts with leſs force.

79. By whatever method the beſieger ſucceeds in rendering the countermines uſeleſs, he ſhould inſtantly proceed to the conſtruction of the ſecond batteries; and for greater ſecurity, keep ſome miners ſtationed in the galleries that he has taken poſſeſſion of, to liſten if the beſieged make any efforts to re-enter.

80. The

80. The countermines under the outworks or ditch, muſt be attacked before the third batteries can be erected.

If the profile of the attacked work be narrow, as that of a counter-guard, for example; two or three holes, diſtant from each other about 50 or 60 feet, ſhould be made near the foot of the revetement by the battering guns; ſloping even for that purpoſe, if neceſſary, the embrazures and the top of the counterſcarp: the wall being thus pierced and the deſcent and paſſage acroſs the ditch completed by the ſappers, the miners ſhould be introduced into each hole, to drive a ſhaft into the terreplein, equal in length to the height of the wall; and having made branches to the right and left, they ſhould make a chamber at the extremity of each, to deſtroy the ſurrounding countermines. If they meet with a branch or gallery, they ſhould endeavour to chaſe the beſieged from it by throwing in fetid combuſtibles; and in the mean time prepare and charge a chamber or two to deſtroy theſe countermines and ſhake down the caſemates: while one party of miners is thus employed, another ſhould explore the communications leading to the countermines under the glacis from the attacked outworks, in order to drive the beſieged from thence by force or other means.

Theſe operations are carried on under cover of an inceſſant fire of muſquetry from all the lodgements that bear upon the ditch, to check the beſieged in any attempt to deſtroy the epaulment, or diſturb the miners.

81. If the attacked work be very ſpacious and the beſieger under the neceſſity of erecting batteries at the gorge; after having deſtroyed the countermines under the breach (80), he muſt effect a lodgment in the gorge by aſſault; and then by ſinking ſhafts endeavour to cut off the communications between the countermines and the body of the place: for this purpoſe the direction given (73) for the attack of the countermines under the glacis may be ſucceſsfully applied. While this is going forward, he ſhould endeavour by means of the ſhafts ſunk upon the capital, or of the countermines he has got poſſeſſion of, to penetrate into the galleries under the gorge of the work, and totally expel the beſieged, aſcertaining by theſe means the ſecurity of his batteries.

82. From theſe premiſes it may be inferred;

1. That to attack a place with two ſtages of countermines, there muſt be a large corps of miners and great

great conſumption of powder; and even then the progreſs of the beſieger will be ſlow, if the garriſon exert themſelves.

2. That it is neceſſary to have an exact plan of the countermines; otherwiſe much time may be loſt in exploring them, or they may be ſo badly diſpoſed as not to merit the trouble of counteracting their effects.

## CHAP. VIII.

### Of the Surrender of the Place.

83. THE artillery will continue firing after the chamade is beat, till ordered to ceaſe by the general of the trenches for the day, or till anſwered by the beſiegers; and every thing will be kept in readineſs for renewing it at a moment's warning.

While the terms of capitulation are ſettling, no perſon is to be ſuffered to reconnoitre the batteries and approaches. When the capitulation is ſigned, and one of the gates of the place taken poſſeſſion of by ſome picquets of grenadiers, the commanding officer of artillery, by order of the commander in chief, will ſend the ſenior officer to receive the artillery; and the ſenior officer of miners, accompanied by one belonging to the garriſon, to examine the countermines. In the mean time the batteries are provided with ſtores, &c. till the place be entirely evacuated.

84. A few hours before the garriſon marches out a detachment of artillery will be ſent to receive the keys of the magazines, and take an account of all arms, ammunition and ſtores; and all places where any articles may have been concealed or depoſited: to be the more exact, the officer commanding this detachment ſhould demand a copy of the inventory of ſtores previous to the ſiege, and an account of the expenditure while it laſted.

Every article that is liable to be ſtolen ſhould be locked up in the magazines, and a ſufficient number of centinels and guards poſted for their protection.

After the evacuation, an inventory of ſtores muſt be made out; the guns, &c. drawn back from the batteries to the park, and every thing prepared for marching: the guns ſhould

ſhould be examined, and their condition reported. The commander in chief will direct whether the town is to be put into a poſture of defence, or the works diſmantled: in the former caſe, the commanding officer of artillery will go round the place accompanied by the officer deſtined to be left in the command of the artillery, and order the neceſſary quantity of ſtores to be completed from the park: if it is to be diſmantled and the works demoliſhed, he will leave the proper quantity of powder, wood and tools, for undermining and blowing up the works, and cauſe all the artillery and the remainder of the ſtores to be tranſported to the places aſſigned by the commander in chief.

## CHAP. IX.

### Of Irregular Sieges and Blockades.

85. SIEGES are termed irregular, when any of the operations requiſite for beſieging a place in form are diſpenſed with. From this definition, it is evident that there are different kinds of irregular ſieges, which vary according to circumſtances. If in the vicinity of a place there be any deep ditches, ravines, or riſing grounds, that may ſave the beſieger the trouble of breaking ground at a diſtance, and carrying on regular approaches; or whence he can directly batter in breach the magiſtral line, and annoy the garriſon in their points of defence; or under cover of which a lodgment may be effected on or very near the glacis, without being too much expoſed: if the garriſon be weak, or compoſed of ill-affected or undiſciplined troops; the profiles of the works not according to the true principles of fortification; or any weak point be diſcovered after the covered way is taken: in any of theſe caſes, the beſieger is juſtifiable in precipitating matters, and omitting ſome of the ſteps taken in regular ſieges.

86. Thus a ſmaller proportion of artillery, or at leaſt of ſtores, is requiſite for irregular than for regular ſieges: and when before the inveſtiture, the beſieger is in poſſeſſion of the neceſſary data (5, 6, 7) he may make out with the greateſt accuracy, a ſtate of the ſtores, and concert meaſures, to bring the expedition to a ſucceſsful concluſion in the

ſhorteſt

ſhorteſt ſpace of time poſſible; which in military operations ſhould ever be a leading maxim.

In irregular ſieges that are of ſhort duration, the batteries for the ſake of expedition are conſtructed with gabions. When there is a ſcarcity of earth, as often happens in mountainous countries, every pioneer brings a ſack filled with earth, which are laid together to form a parapet. In conſtructing batteries on a rock, wool-packs are preferable to ſacks of earth.

87. In beſieging towns ſurrounded with a ſingle wall, or old caſtles, there is ſeldom a neceſſity for breaking ground, and never for making regular approaches; a field battery being generally ſufficient for making a breach: it ſhould be made in that part of the wall which leads to ſome ſquare or ſpacious place, where the infantry after the aſſault may draw up in order to attack the garriſon, in caſe they have retired behind intrenchments or palliſadoes. The diſtance of the battery from the place ſhould be about 400 yards; it may be conſtructed with caſks or gabions ranged in two rows, and filled with earth; openings made in a garden wall or other building, may occaſionally ſerve for embrazures, and a plank may be laid under each wheel by way of platform, unleſs the ground be firm enough without it.

88. With proper information concerning the ſtate of the place previous to its inveſtiture, the number of attacks, and the quantity of ſtores requiſite for each, may be eaſily aſcertained; thus, the garriſon being diſtracted by ſeveral attacks at once, may be the ſooner compelled to ſurrender. The general rule is to allot four or ſix 24 or 32 prs. to each attack, and 100 or 200 rounds for each gun, in proportion to the ſolidity of the works: the quantity of intrenching tools is regulated by the trenches intended to be opened.

89. A breach is ſometimes made when the artillery is inſufficient for the purpoſe, by undermining the wall: the miners are lodged in an opening not expoſed to the fire of the garriſon, and a ſhed of planks covered with ſand-bags or raw hides, erected to ſhelter them from the hand-grenades or combuſtibles that the enemy may throw down from the wall: they then proceed to make the mines in the ſame manner as in the demolition of places.

If there be an aqueduct or ſubterraneous canal that paſſes under the wall, the miners ſhould lodge themſelves in it; and in the firſt place, form a barricado to ſecure themſelves againſt

againſt the enterprizes of the enemy; and then in the ſides of the canal excavate one or two chambers large enough to make a breach in the wall. In every caſe, the miner ſhould be ſecured againſt the attacks of the garriſon, by poſting ſome grenadiers at proper places, and if neceſſary, by raiſing an epaulment acroſs the ditch to the foot of the wall; which may be eaſily effected under cover of a fire of muſquetry, by the means of wool-packs or mattraſſes.

90. When the gates of a town through the negligence or ignorance of the garriſon are inſufficiently guarded, or badly conſtructed, they are ſometimes forced open by petards: it is the buſineſs of the artillery-men to fix them: they are ſupported by the detachment of infantry intended to ruſh into the town the moment the gates are burſt open.

The party deſtined for this ſervice approach ſecretly during the night, and ſcrew an iron hook into the gate, on which they hang the petard with its bottom flat againſt the gate, and propped behind by a ſtrong iron fork: the fuſe is then ſet fire to, and as ſoon as the petard takes effect, the column of infantry ruſhes in. As the opening made by the exploſion of the petard may not be large enough to admit the men, ſome carpenters ſhould be in readineſs with their axes to cut away any obſtruction.

91. *Blockades* are ſo termed when the beſieger having inveſted a place, and carried on regular approaches, ſuſpends his operations either through choice or neceſſity; confining himſelf to keeping up a fire from his artillery. This method of attack is practiſed in the following caſes:

1. When a town is unprovided with caſemates and magazines: whence the beſieger may have reaſon to hope that by keeping up a continual fire, the inhabitants may be ſo harraſſed as to riſe againſt the garriſon; or at leaſt, that a part of the ammunition and proviſions may be deſtroyed.

2. When a town full of inhabitants, ſtrongly fortified, and well provided with troops, artillery, and ammunition, is deſtitute of ſufficient ſupplies of proviſions to ſuſtain a ſiege: from which circumſtance, the governor may in a ſhort time be induced to ſurrender, provided that by the inveſtiture his conduct is apparently juſtified.

3. When from moraſſes, inundations, rocks, ravines, or precipices, it is found impracticable to carry on the approaches

approaches in any manner likely to bring the ſiege to a ſpeedy termination.

4. When from bad roads, or other circumſtances, the artillery is inſufficient to proſecute the ſiege with vigour.

92. In the firſt and ſecond caſe, the engineers make trenches of communication from different parts of the line of circumvallation, at the diſtance of 700 or 1000 yards from the body of the place, and batteries mounted with heavy cannon are erected by the artillery-men: each battery is incloſed in a redoubt of reſpectable profile, and ſpacious enough to contain a guard ſufficient to ſecure it againſt any attempts of the garriſon. Guards are likewiſe poſted in the hollows or ravines in the vicinity of the battery; and when the ground is level, detachments are placed in the intermediate parallels, between the communications, to ſuſtain the redoubts, and give time to the troops at the camp to come to their aſſiſtance in caſe of a general ſally: but if the batteries be covered by a river, canal, moraſs, precipice, or defile, a ſtrong guard in each redoubt will be ſufficient for their ſecurity.

93. In the third caſe, (91), the beſieger muſt exert himſelf to turn every acceſſible point, whence the town can be annoyed either with ſhot or ſhells, to the greateſt advantage, by planting on them a proper quantity of artillery of large calibre.

The proportion of ordnance for this kind of ſiege is greater than for regular ſieges, particularly when the blockaded town is very large; unleſs in regular ſieges, a fire is directed from every ſide on the moſt populous quarters of the town, in order to excite conſternation and terror among the inhabitants.

94. In the fourth caſe, the lines or trenches judged neceſſary on the occaſion, ought to be conſtructed with a view to their being uſeful, when an adequate quantity of artillery arrives, to convert the blockade into a regular ſiege; the vivacity of which muſt depend on the knowledge the beſieger has acquired concerning the ſtrength of the garriſon, the ſtate of the fortifications, and the nature of the adjacent country.

An army ſometimes ſits down before a place of great importance, in hopes of inducing the enemy to abandon an advantageous poſt in order to relieve the place, and perhaps hazard a general engagement. The moſt vigorous attack

attack ſhould be made in this caſe; which will induce the enemy to march with greater expedition to raiſe the ſiege.

95. Whatever be the motive for undertaking this kind of ſiege, the batteries ought to be amply furniſhed with cannon and mortars; they ſhould be fired at different elevations from 8° to 12° that the ſhot and ſhells may be thrown into every quarter of the town: and if there be a probability of ſetting fire to any of the principal edifices or magazines, hot-ſhot ſhould be inceſſantly fired.

From a review of every circumſtance attending the commencement and progreſs of ſieges, it will appear that from the opening of the trenches until the ſurrender of the place, the nature of the ſiege may, from the variety of incidents to which military operations are peculiarly liable, be frequently changed.

## CHAP. X.

### DIRECTIONS FOR DEMOLISHING THE FORTIFICATIONS OF A CITY.

96. IT is generally deemed ſufficient to demoliſh the revetements of the works, and blow up the magazines, caſemates, &c.; the deſtruction ſeldom extends to the terre-plein, from the great expence and labour it would coſt.

The chambers of mines for demoliſhing a building, the wall of which is not more than 7 feet thick, are of a *cubical form*, with one of the ſides correſponding to the ſide of the wall; but if the thickneſs of the wall exceed 7 feet, chambers are made in a *hemiſpherical form*, in the centre of the wall.

97. The following are the general principles to be obſerved in the diſpoſition of mines:

1. The chambers ſhould be made at the foundation, that the upper part of the building may be raiſed and ſhaken to pieces;

2. And, if poſſible, ſome feet below the ſurface of the ground on which the wall ſtands; as from the great reſiſtance the exploſion is more violent, and the effect greater: mines placed near the ſurface of the ground

ground ſometimes act but upon one ſide, and cauſe a breach in the wall inſufficient to deſtroy the building.

3. If the ſolidity and ſtrength of a building depend on its counterforts, chambers ſhould be made in them, though they be above the ſurface of the ground.

4. The largeſt chambers ſhould be placed under the ſtrongeſt parts, where the maſonry has moſt ſolidity and coheſion; as at the point of interſection of croſs vaults, and large buttreſſes or pilaſters ſupporting roofs and arches.

5. In walls that are without any break, the chambers ſhould be 12 or 15 times, the ſide of the cube or the diameter of the hemiſphere, according to its figure, diſtant from each other.

98. The ſize of the chamber depends on the quality of the powder, the thickneſs of the wall, and the coheſion of the materials of which it is built; which differs in different climates according to the quality of the lime, and the time it has ſtood. The coheſion of walls raiſed above the earth, and cemented by the beſt lime and ſand of *Piedmont* and *Lombardy*, is generally eſtimated at 16400lbs. for every 20 ſquare inches; while that of ſubterranean walls cemented with materials of certain qualities, as the lime of *Superga* or *Caſal* in *Montferrat*, and the ſand of *Trebia*, is more than double. The coheſion of walls conſtructed on the coaſt of *Provence* and *Genoa*, exceeds 41000lbs. and that of buildings adjoining to the ſea, and cemented with *Pozzolana*, is frequently triple.

The officer of miners, therefore, charged with the demolition of any place, ſhould previouſly aſcertain by experiment, the tenacity of the wall. The ſide of the cubical chambers ſhould be a third part of the thickneſs of the wall, ſuppoſing its tenacity to be 16400 lbs. and the powder very ſtrong. The ſame rule will ſerve for the diameter of the hemiſpherical chamber; its depth ſhould be about $\frac{2}{7}$ of its diameter: its contents will then be about half as much as the cubical chamber. By the table (77), the quantity of powder for a cubical chamber of a given ſide may be eaſily determined.

99. To give an idea of the diſpoſition of mines, the figure repreſents the plan of an inſulated building, the roof of which is bomb-proof; (Fig. 4, Pl. 4) the principal chambers are made under the points A, H, I, K, L, M, N,

O, P, where the walls interſect, and under the pilaſters Q which ſupport the fronts A B, C D, and on which the roof reſts (97, No. 4). The chambers in the wall F F which is without any break, are diſtant from each other, and from the principal mines, 12 or 15 times the lenght of the ſide or diameter (97, No. 5); and if in the faces A B, C D, the chambers A, H, I, be too far diſtant to have proper effect, two intermediate ones S, S may be made. The wall G G in which are the chimnies and doors of communication, need not be undermined; but the ſize of the principal chambers K, L, M, ſhould be increaſed by about $\frac{1}{4}$. The mines thus diſpoſed may be divided into two claſſes; viz. thoſe made in ſingle walls, as Q R, S, and thoſe made in croſs walls, as A H, &c.

100. In this profile P P repreſents the plane of the ground ſurrounding a building: (Pl. 4, Fig. 5) the walls are ſingle, and the chambers are to be of a cubical form: to make the excavation in the foundation D A E, below the plane P P (97, No. 1, 2), let a long trench be dug $1\frac{1}{2}$ of the thickneſs of the wall D E in depth as D B, and $3\frac{1}{2}$ feet in width as C D. Let the chamber G of a cubical form, be made $\frac{1}{3}$ of B D diſtant from the bottom B F, and a wooden box of proper dimenſions for containing the quantity of powder aſcertained by preceding experiments (98) placed in it; and if there be any reaſon to apprehend that the powder may be damaged by the moiſture of the wall, let the box be lined with oil-cloth. At the mouth of the chamber make a ledge H, 3 inches broad, and of a depth proportioned to the ſize of the planks that are to cloſe the opening. Any projections or cavities in the wall where the trench is dug, ſhould be ſmoothed or filled up with well worked plaiſter. The planks for blocking up the chamber ſhould be 2 inches, and the beams 5 or 6 inches thick, and a quantity of clay and rotten dung, (which is excellent for preventing the eſcape of the inflamed fluid) prepared. The box being filled with powder, and a fauciſſon laid in a pitched wooden trough, communicating with it, the opening is exactly cloſed; planks called mantlets as C F K L, B D I M, are placed vertically along the faces of the trench, and the beams N are driven in horizontally at right angles to the mantlets, and all the interſtices filled with clay and dung well rammed.

101. To

101. To make mines of a cubical form in a croſs wall A B; let C, D, E, F repreſent a ſquare pit hollowed in the adjoining ground; (Pl. 4, Fig. 6) the ſide of which is 4 ½ feet, and the depth 1 ½ of the thickneſs of the ſtrongeſt wall. At about ⅓ from the bottom, hollow out in the wall B a branch F N G H 3 ½ feet high, 2 ½ feet wide, and ½ of the thickneſs of the wall B in length; then in K B the centre line of the wall B make the chamber K of a proper ſize: let a box be fitted to it, and at the mouth of it make a ledge F H. Let the box be filled with powder, the ſauciſſon applied, and the opening I cloſed and blocked up with beams laid horizontally to L G: let the opening F N be cloſed in the ſame manner as I; and diſpoſing the mantlets around the ſides of the pit, drive in horizontal layers of beams croſſing each other alternately at right angles, till they reach the ſurface of the ground, always filling the interſtices with dung and clay, and taking care to bring out the ſauciſſon. It ſhould be remarked here, that though in this caſe, where it is intended to blow up a greater extent of wall, the ſame charge is uſed as in the preceding paragraph; yet greater reſiſtance being oppoſed to the exploſion of the powder, the effects will be proportionably greater.

102. If the wall be more than 7 feet thick, (Pl. 4, Fig. 7) the chambers ſhould be hollowed in a hemiſpherical form, in the following manner: A A is the profile of a ſingle wall; dig a ſquare pit B D C F the ſide of which is 4 ½ feet; then make the branch B L G E 3 ½ feet high, and of ſuch a length and breadth, that the chamber K hollowed out in the centre of the wall, may contain half the quantity of powder that a cubical chamber, the ſide of which is equal to the diameter of the hemiſphere would contain: at the mouth of the chamber make the ledge H H, and ſmooth the roof and bottom of the branch with well worked plaiſter. Having charged the mine, applied the ſauciſſon, cloſed the opening H, and laid two layers of mantlets horizontally, the one B Q L O on the bottom, and the other G E N M on the roof of the branch, drive between them ſtrong beams R; then cloſe the entrance B E, and placing other mantlets againſt the wall and the oppoſite ſide C F, lay rows of beams horizontally between them, filling all interſtices with clay and dung, and carefully bringing out the ſauciſſon.

103. The figure repreſents the plan of two walls which interſect each other, and exceed 7 feet in thickneſs: (Pl. 4

Fig. 8) to determine the exact position of the chamber, draw the right line B B dividing into two equal parts the wall B, and another right line A A parallel to C C, and distant from it $\frac{2}{3}$ of the thickest wall A; then the point of intersection K will be the centre of the chamber, which should be $\frac{1}{4}$ larger than that made under a single wall. Make a square pit C D E F, the side of which is $4\frac{1}{2}$ feet; and in the wall A make the branch G H L M D, with an elbow or angle, and of such a length that the chamber may be hollowed in K: let it be loaded and blocked up as before (102); at M N close the opening with a frame, and lay horizontal layers of beams unto the opening D G, which should be well closed, and placing mantlets against the sides C D, E F, drive in horizontal layers of beams till the pit is filled, ramming dung and clay in all the interstices.

104. To undermine revetements; make pits in the ditch close to the revetement 6 or 7 feet deep: then piercing the wall, carry on in the terreplein two branches, the one to the right and the other to the left, at the extremities of each, and at the points where the revetement is supported by the counterforts, hollow the chambers (101), either cubical or hemispherical (103) according to the thickness of the wall, so that the two chambers on each side of the opening may correspond. In the proper disposition of counterforts to support revetements, the strongest points are at the flanked angles; viz. those of the shoulder and flank; the principal chambers should therefore be made in these angles, the others may be distributed along the walls that form the angles. If the revetement be built on a rock, and of no great thickness, the number of chambers should be increased and brought nearer together, that the whole revetement may be thrown down at once.

As the manner of charging mines in revetements is the same as that before described, we will dismiss this subject for the present; only remarking that in blowing up stone or brick bridges, the chamber should be made in the foundation of the piers, or in the shoulders of the arches. It frequently happening on service, that a tower or other slight building is to be instantly demolished: it may be effected by placing in the ground story some open barrels of powder close to each other, blocking up the doors and windows with strong planks, and covering the floor above with a thick layer of earth; then setting fire to the sauciſſon that communicates with

with the powder, the great reſiſtance oppoſed by the earth upon the upper floor, prevents the powder from acting upwards, and directs its force againſt the walls of the tower, which being of no great ſolidity, eaſily yield and fall down.

# SECOND PART.

## Of the Service of Artillery in the Defence of Places.

105. THE ſcience of defence conſtitutes one of the moſt eſſential branches of the military art, ſince a few troops are thereby frequently enabled to make head againſt a very ſuperior army, to the preſervation of a whole country: and as in the proſecution of this ſyſtem, the inferior army is often compelled to ſuſtain a ſiege, the defence of places forms one of the moſt important parts of this ſcience. Now the defenſive ſyſtem may either be the reſult of a premeditated plan; or a nation may be unexpectedly forced into it by the ſudden invaſion of a foreign enemy, or by a train of unfortunate events, that oblige an army which began the war with the faireſt hopes of conqueſt, to change its ſyſtem and act on the defenſive.

106. When a defenſive war is foreſeen, ſome of the ſenior officers of artillery are ſent to inſpect the quality and number of arms and ſtores of all ſorts in the different garriſons; examine the condition of the magazines, works, and countermines; and take notes of every thing that may be wanting in caſe of a ſiege.

After the inſpection, each officer makes a report in writing of the number and nature of artillery and carriages, with his propoſed arrangement of them; and alſo of the proportion of tools, machines, arms, and ammunition, which in his opinion may be adequate in proportion to the ſtrength of the garriſon, for making a vigorous defence;

he farther explains the motive of each demand, and points out the place where every article can be lodged; diſtinguiſhing the magazines that are bomb-proof, and remarking particularly any that ſhould be made ſo, previous to a ſiege.

An engineer is likewiſe detached to each fortreſs to report the number of troops neceſſary for its defence; make out a diſtribution of barracks and magazines; and examine the repairs and alterations for putting the fortifications in a proper ſtate of defence, with the quantity of palliſadoes and faſcines for repairing the damage, that the enemy's artillery may do to the works during the attack.

The governor then calls a council conſiſting of the artillery officer, engineer, and ſtaff of the garriſon; where the merits of the two reports are canvaſſed, and thoſe propoſitions adopted that appear conducive to the beſt defence: the opinion of the council is then ſubmitted to the ſovereign for his deciſion, who orders the neceſſary mines and works to be conſtructed, and the ſtores to be provided. When they arrive in the garriſon, they are depoſited in the magazines allotted in the plan for each particular ſpecies.

107. But if a ſtate be ſurprized into the defenſive ſyſtem, the officer commanding the artillery in a place menaced with a ſiege, ſhould make the ſtore-keeper give him an actual ſtate of the diſpoſition and condition of every article under his charge, and immediately examine thoſe that are of the moſt importance: and in his report to the governor, ſhould particularize what may be wanted in addition to the quantity at preſent in ſtore, or to replace any that may be damaged. But if from the approach of the enemy, there be little probability of having ſufficient time to draw the ſupplies from the arſenals or neighbouring garriſons, every thing in poſſeſſion of the inhabitants that may be uſeful during the ſiege, ſhould be taken after a juſt valuation, and proper receipts given by the ſtore keeper to each proprietor. In forts where no ſuch reſources can be had, parties ſhould be ſent into the neighbouring towns and villages to ſeize and conduct to the garriſon every thing they can find that may be of ſervice during the ſiege. It is the maxim of every good government, to complete the ſtores of all frontier towns on the leaſt apprehenſion of a war.

CHAP.

## CHAP. I.

### Of the Dispositions for the Regular Defence of a Place previous to its Investiture.

108. THE firſt diſpoſition that an officer of artillery ſhould make for the regular defence of a place, is to form a ſtate of the number and nature of guns, carriages, and ſtores. To do this with juſtneſs and preciſion, he ſhould recur to the rules laid down in the former part of this treatiſe, and be not only acquainted with the ſervice of artillery in all its branches, but capable alſo of judging in the fulleſt extent of all operations, in which the other troops of the garriſon can bear a part; ſo that every thing may be adequate to its particular purpoſe, without deficiency on the one hand, or ſuperfluity on the other. Thus two extremes equally prejudicial will be avoided; the one of making a proviſion of ſtores inſufficient for the defence the place is capable of; the other of providing ſuch quantities, that on the ſurrender of the place, a complete arſenal may fall into the enemy's hands.

109. The fundamental maxim in the defence of places, *is to retard as much as poſſible the progreſs of the beſieger, and in proportion as he advances to multiply his dangers and difficulties.*

To this end, the artillery-officer ſhould examine on the ſpot, the natural obſtacles that the beſieger may have to ſurmount in the attack of the works, and countermines; and after maturely weighing the weak and ſtrong points, ſhould conſider how far the advantages of each front may be improved, and the defects remedied. Any ſtrong poſition in the vicinity of the place, ſhould, if poſſible, be rendered uſeleſs to the beſieger; and every vulnerable part ſtrengthened by additional works. If the firſt poſition that the enemy muſt from the nature of the ground take up, be very confined, the proportion of artillery and ſtores may be made out with the greateſt accuracy, and there will be good reaſon to reckon on a ſucceſsful defence; as the enemy will of courſe be extremely circumſcribed in all his operations. But when he is free to chooſe his poſition, the artillery

officer ſhould be informed whether the artillery the enemy can bring up be only adequate to a regular ſiege, or ſufficiently numerous to enable him in a few days to beat down all the defences on the front of the attack, and keep up ſuch a continual fire as to prevent the garriſon from repairing the damages.

110. The preſent treatiſe ſuppoſes a fortreſs beſieged in form; whether from the poſition that the beſieger is obliged to take up, or from the inſufficiency of his artillery to take advantage of one more extended. Thoſe violents attacks, where the defences are in a few days deſtroyed by the firſt batteries, and the garriſon prevented from repairing them, ſeldom occur but in ſmall places: ſuch examples are very rare in places of ſtrength and importance; particularly when the enemy is obliged to bring his artillery by land, from the prodigious number of carriages and horſes required for the tranſport. But if from circumſtances there be reaſon to apprehend a ſiege of this nature, the ſtate of the magazines and barracks ſhould be examined, and any that are expoſed to be cannonaded covered with ſubſtantial epaulments. When the profiles of the works are ſo advantageous that the beſieger muſt effect a lodgement on the glacis before he can make a practicable breach; the moſt effectual mode of retarding his progreſs is by countermining with the utmoſt diligence. But when the barracks and magazines are ſecured; a breach in the body of the place impracticable from its being cut out of a rock; or, when made, is rendered inacceſſible by ſome natural or factitious obſtacle; every attempt on the part of the enemy will be futile, provided the garriſon conduct themſelves properly in this caſe, where perſeverance and firmneſs, rather than courage and exertion are requiſite.

111. The firſt ſtep towards forming the eſtimate of ſtores for ſuſtaining a regular ſiege in a fortified town, is to conſider what front is moſt attackable, and what are the beſt meaſures to be adopted for its defence. But as the beſieger may through incapacity or ignorance commence his attack on the ſtrongeſt ſide, the proportion of ſtores ſhould be large enough to take advantage of this error; and to avoid extremes (108), the defence of the two fronts ſhould be carried to the ſame point, either by raiſing new works, countermining, or diſpoſing to greater advantage and ſtrengthening the old works. But if the ſhortneſs of time doth not admit

of

of this, two eſtimates ſhould be made out; one for the defence of the ſtrongeſt front; the other, of the weakeſt; that the *Sovereign* may determine which of the two he thinks proper to adopt.

112. 32 and 16 prs. are mounted in the body of the place; 12 and 8 prs. in the outworks that are large enough to contain them: when the adjacent country is favourable for making ſallies, or conſtructing lines of counter-approach, ſome light 4 pounders are included in the inventory. It was the cuſtom in the laſt century to place ſome pieces of large calibre, reſembling ſtone-guns or long howitzers, on the flanks, from which, when the aſſault was given, they fired caſe or grape-ſhot on the aſſailants: but theſe pieces are now diſuſed, ſince the beſieger covers himſelf with epaulments in the ditch and at the breach: inſtead of them, we fire round ſhot from heavy guns, to deſtroy, or at leaſt retard the conſtruction of, the epaulments.

113. In fortified towns conſtructed on mountains or eminences, the embrazures are generally made of brick or ſtone, and the curtain furniſhed with guns, when it bears on any poſition favourable to the beſieger; the number of guns muſt in this caſe be regulated by the number of embrazures. But when the parapet is formed of earth, the following is the diſtribution of guns on each front: 10 or 13 toiſes are left on the faces of the baſtions, and 6 from the angle of the ſhoulder to the flanked angle for the barbette batteries; the remainder is divided ſo, that there be never leſs than 20 feet between every two embrazures, to give room for the infantry, whoſe fire, when the enemy comes within muſquet ſhot, is the moſt effectual method of retarding his progreſs; and with leſs diſtance between the embrazures, the merlons would be ſoon deſtroyed by the enemy's artillery: the ſame rule ſhould be obſerved in opening embrazures in the outworks.

A few guns ſhould be added to the above diſtribution, for the barbette batteries on the other fronts, and for the flanks correſponding to the attack.

114. To determine the number of guns for the four faces of the ravelins correſponding to the attack, 10 or 13 toiſes are allowed for the barbette batteries in the collateral ravelins, and the remainder divided into equal parts with intervals of 20 feet for the embrazures; but in the ravelin on the front of the attack, a greater ſpace is left from the ſaliant

angle

angle for the barbette batteries, to avoid being enfiladed or taken in reverſe on the adjoining face.

Pl. III. With a counter-guard before the baſtion 10 or 13 toiſes are ſet off from the ſaliant angle for the barbette, 2, 3, and embrazures opened at 3, 4 of the face correſponding to 5 of the barbette on the baſtion, when the height of the baſtion above the counter-guard is leſs than 10 feet; but when it is 15 feet or more, the whole face of the counter-guard ſhould be lined with cannon, in order to have two ſtages of fire; as there will be no danger of the lower work being incommoded by the fire of the upper one. In the counter-guard before the ravelin, the ſame precaution ſhould be attended to. Guns on the faces of horn or crown-works large enough to contain them, ſhould be in the ſame proportion.

115. The guns on the front of the attack ſhould be of braſs, as they ſtand firing for a long time: on principles of œconomy, iron guns may be planted on the parts whence a very heavy fire cannot be kept up; as the barbette batteries on the fronts not attacked, and the points which there is reaſon to apprehend the enemy may endeavour to carry by aſſault.

116. The moſt advantageous and at the ſame time moſt œconomical uſe to which mortars can be applied in the defence of places, is to project ſtones and royal ſhells upon the approaches and lodgments of the beſieger. There is ſo much uncertainty in the range of ſhells fired from large mortars againſt the firſt batteries of the beſieger, notwithſtanding all poſſible attention in the bombardiers, that they are only employed at great diſtances to project ſhells filled with combuſtibles, for diſcovering the progreſs of the beſieger during the night, when the diſtance is too great for light balls; but when the beſieger approaches within the reach of light balls from the ſtone-mortars, the large mortars are then reſerved for enfilading the batteries and lodgements on the creſt of the glacis, and deſtroying the ſhafts and ſlopes which the beſieger has ſunk on the glacis and covered way for the attack of the countermines. Hence, an officer aware of the manner in which the beſieger can direct his attacks will neceſſarily conceive that two mortars of each nature ſhould be employed againſt each approach, and againſt each of the batteries in breach expoſed to be enfiladed.

117. The

117. The fire of the infantry is, as has been already obſerved, one of the moſt effectual methods of retarding the progreſs of the beſieger. But in keeping up a continual fire during the night, the muſquets being thin ſoon become unſerviceable; wall-pieces being better reinforced are more ſerviceable and leſs apt to burſt. The greater part of theſe arms are mounted with locks, of which the cocks are of a ſerpentine form according to the cuſtom of the laſt century; but the troops being unaccuſtomed to make uſe of them, it would be much better if they were furniſhed with common locks, with the uſe of which the infantry are perfectly acquainted. The proportion of wall-pieces ſhould exceed by a half, the number of infantry deſtined for the daily defence of the covered way, for a ſiege of 30 days; for one of longer duration, the number ſhould be increaſed.

There ſhould alſo be a reſerve of muſquets with bayonets, to ſupply the place of any that may be damaged: for a ſiege of 30 or 40 days, the number in reſerve ſhould exceed by a third the number of infantry in garriſon. Some large wall-pieces are alſo provided for firing at a diſtance againſt reconnoitering parties of the beſieger.

118. There is no abſolute rule laid down by military authors, for determining the number of men for the defence of a place beſieged in form. The moſt general and unexceptionable one is, to reckon 3 men for every 10 feet in the covered way, on the front of the attack, including the two collateral places of arms; when the town is fortified in the common method with no outworks but ravelins. If the body of the place be conſtructed on a ſyſtem of demolition; the fire from the flanks command the points where the enemy muſt erect his counter-batteries; or there be counter-guards before the baſtions, the reſt of the works being in the common method; then 4 men are allowed for every 10 feet. With counter-guards before the ravelins; or when with ravelins only, there is one ſtage of countermines, the number is eſtimated at 5: with two ſtages of countermines; or the body of the place conſtructed upon a ſyſtem of demolition and covered by other outworks beſides ravelins, at 6.

If to the number of men reſulting from this eſtimate, be added the neceſſary guards for the parts not on the front of the attack, the gates, ditches, magazines, &c. and the whole be

be tripled; the result will give the proper ſtrength of the garriſon for a regular ſiege.

In mountainous ſituations, where there is no covered-way, two men are allowed for every 10 feet along the magiſtral line of the front attacked, including the outworks; to this add the neceſſary guards, and the ſum tripled will give the number of the garriſon.

119. For example; ſuppoſe a regular pentagon, of which the line of defence is 134 toiſes; this gives 56 toiſes for the faces of the baſtion, and 25 toiſes for the flanks; let the profiles of the ravelins, which are ſuppoſed to be the only outworks, admit cannon. The following will be the diſpoſition of artillery.

| | No. of Guns. | |
|---|---|---|
| | *Braſs.* | *Iron.* |
| On the two faces of the baſtion on the front attacked | 20 | — |
| On the two faces of the collateral ravelins | 12 | |
| On the two faces of the ravelin between the baſtions | 12 | — |
| On the barbette batteries and flanks | — | 18 |
| Total | 44 | 18 |

This number, deſigned for the firſt part of the direct defence, will be more than adequate for the ſecond part; two or three light 4 prs. may be added for ſallies or counter-approaches, when this mode of defence is practicable.

If the place be hexagonal with a line of defence of 134 toiſes, and the flanks a little longer, two pieces of braſs and two of iron ſhould be added to the above proportion.

Suppoſing the beſieger can carry on his approaches upon the capitals of the baſtions and ravelin, and erect batteries in breach on the creſt of the glacis; the number of mortars will be at leaſt

| | |
|---|---|
| 6 | Stone-mortars |
| 6 | Royal ditto |
| 4 | 10 inch ditto |
| 4 | 13 inch ditto |
| Total 20 | |

If

If the garrison consist of [illegible] of whom are constantly on duty, and [illegible] of [illegible] in a constant fire; there should be [illegible] wall-pieces and [illegible] musquets in reserve; with 10 or 12 large wall-pieces, for firing at reconnoitring parties.

120. This proportion is adequate to the defence of a place in a level situation, where the guns, &c. may be easily transported from one part to another: but if the ground be so uneven, that in the interior communication between bastion and bastion it is impossible to remove the artillery without making use of capstans or other machines, then each attackable front must be furnished with its proportion of artillery; and that there may not be a necessity of increasing the quantity of ammunition in the same proportion, guns of the same nature should be placed on each front; since by that means the ammunition intended for one front will answer equally well for all the others.

If in the vicinity of a place situated in a hilly or mountainous country, there be any hollows not commanded by the cannon of the ramparts, in which the besieger may lodge himself to the great annoyance of the garrison, a proper number of stone, royal, and 10 inch mortars should be provided for firing into them.

121. The number of rounds for each gun depends on the quantity of the besiegers artillery, and the length of the siege. If the position that the besieger must take up be so confined, that the besieged can oppose gun to gun, and have some pieces in reserve for firing at the heads of the sap, &c. the daily expenditure may be calculated at sixty rounds a gun (20), in the first part of the direct defence: but if from the nature of the ground the fire of the besieger be superior by a third to that of the place, half of this number will be sufficient; for the garrison will be frequently obliged to slacken the fire, and probably many guns will be dismounted, With regard to the second part of the direct defence, the daily expenditure may be estimated at 20 or 30 rounds each, for those guns which from the small command of the lodgments on the crest of the glacis, can plunge into the batteries in breach erected opposite to them; and double this number of rounds for the guns that flank the epaulments raised by the besieger in the ditch: the expenditure depends greatly on the fire that the enemy's musquetry can keep up up against the embrazures of the place.

The

The mortars always being placed under cover of the ramparts cannot be affected by direct firing: the interruption from curvelinear projections may be reckoned at about $\frac{1}{6}$ of the whole number of diſcharges that could be made from them in 24 hours; as this is generally computed at 60 from each mortar, it is thus reduced to 50. They may begin to fire with effect when the enemy is advanced within 134 toiſes of the covered way. From memorandums of the quantity of ammunition daily expended by the infantry, in ſome of the moſt conſiderable ſieges, it appears that each ſoldier on duty on the front of the attack, fires from 35 to 40 rounds a day: now ſuppoſing the ſame number of men always to mount guard, from the day that the trenches are opened till the place ſurrenders; the full expenditure may be computed at 50 rounds a day for each man on duty, including the allowance for ſorties. The barbette guns, and wall-pieces ſhould be provided with 200 or 250 rounds at moſt.

122. In calculating the duration of a ſiege, the natural advantages of the place for retarding the progreſs of the beſieger, and the obſtacles he muſt ſurmount before he can lodge himſelf in the different works, muſt be conſidered.

Suppoſe the place be ſuch as repreſented in paragraph 119; that a practicable breach is effected in the baſtion; and that the garriſon is not in a condition to ſuſtain a general aſſault; the duration of the ſiege if the beſieger has been active and enterprizing will have been about 40 days, viz.

| | Days. |
|---|---|
| From the opening of the trenches till the lodgment is compleated on the creſt of the glacis ..... | 15 |
| For conſtructing and completing the batteries in breach ..... | 4 |
| For making a breach in, and getting poſſeſſion of the ravelin ..... | 7 |
| For making a lodgment in the breach in the baſtion | 4 |
| Total | 30 |

When there are more outworks; or the baſtions are conſtructed on a ſyſtem of demolition, ſo that the beſieger is obliged to bring up guns through the breach to batter the interior works, the defence may be prolonged for 10 or 12 days;

days; and even for 25, if there be ſmall mines in the ditch, to blow away the earth and ſtones, beat down in making the breach in the baſtion.

With counter-guards before the baſtion, the ſurrender of the place may be retarded 12 or 15 days: with one ſtage of countermines properly diſpoſed under the glacis, the defence may be prolonged 20 or 25 days; and with two ſtages of countermines, 40 or 50 days: thus with counter-guards before the baſtions, and mines under the glacis, ditch and baſtions, ſuppoſing the latter to be conſtructed on a good ſyſtem of demolition, the defence of 30 days may be prolonged to 80 or 90, provided the proportion of ſtores be ſufficient.

123. The number of rounds from each ſpecies of fire-arms having been thus regulated, it will be eaſy to apportion the quantity of ſhot, ſhells, grenades, lead and powder; allowing for each charge the quantity mentioned in paragraph 22: the allotment of powder for the countermines is to be computed from a general conſideration of their number and extent.

To this proportion ſhould be added 100 rounds of caſe-ſhot for every flanking gun; and a competent number of hand grenades, and large ſhells, for rolling from the top of the breach upon the beſieger, when he has puſhed forward his epaulment to the foot of it; this number may be eſtimated at 1000 grenades, and 100 ſhells a day for each breach.

124. For a ſiege of one month, the number of ſpare carriages and ſide-arms amount to half the number of guns; for a ſiege of ſix weeks, this proportion ſhould be doubled; beſide ſpare wheels and axle-trees. The mortar beds, &c. are in the ſame ratio. In caſe of aſſault, a number of pointed and cutting inſtruments, as eſpontoons and ſcythes, ſhould be provided: and ſome petards, blunderbuſſes and piſtols for the ſervice of the countermines.

The neceſſary articles for a complete laboratory, and for making up every ſpecies of combuſtibles form a very eſſential part of the ordnance ſtores; the quantity of the latter ſhould be ſufficient to light during the night the whole front of the attack, and to ſet on fire every part of the beſiegers works that can be burnt. The carpenter's, blackſmith's, and armourer's tools for repairing the damaged arms are likewiſe included in the proportion of ſtores.

In the diſtribution, a particular remark ſhould be made of the ſtore houſes, in which the articles that are generally locked up

up are to be depoſited; diſtinguiſhing thoſe that may be wanted for common uſe, from thoſe that can be only wanted in caſe of a ſiege: likewiſe the laboratory, carpenter's, blackſmith's, and armourer's ſhops. In very large towns they are generally fixed in ſome buildings at a diſtance from the attack; but in citadels, forts, caſtles, and ſmall places which are expoſed on every ſide, they muſt indiſpenſably be ſecured in bomb-proofs. The powder magazines are the moſt important and hazardous of all; they ſhould be dry and ſecure. During the ſiege the powder ought to be diſtributed in ſeveral bomb-proof magazines at a diſtance from each other; that in caſe of accident, the whole may not be blown up at once; and that the enemy may not be able to find out the quantity in ſtore. The nature alſo of the places in which the different articles are depoſited ſhould be attended to: ſince the powder, ſaltpetre, ſulphur, cordage, iron, &c. ought to be depoſited in dry places; whereas the greaſe, oil, pitch, candles and other articles ſubject to melt or evaporate, ſhould be kept in very cool places. It being the duty of the engineers during the ſiege, to keep all the parts of the works in a proper ſtate of defence, they are to make returns of the quantity of ſpare faſcines, gabions, pickets and palliſadoes, that may be neceſſary for that purpoſe: There is no danger of providing too great a number of theſe articles; for any that are not uſed in the repair of the works, may be collected together in the breach, and ſet on fire; which will ſerve to prolong the defence of the place.

125. The following is a particular ſtate of the quantity and quality of the different ſpecies of ordnance ſtores requiſite for ſuſtaining a ſiege of 30 days in a fortreſs N N, (119).

Proportion of Guns, Carriages, Ammunition and Stores.

Ordnance, Carriages, and Side-arms.

| | Nature. Pr. | No. |
|---|---|---|
| Braſs guns | 32 | 12 |
| | 16 | 18 |
| | 8 | 12 |
| Iron ditto | 8 | 18 |
| Braſs ſhort ditto | 4 | 4 |
| | Total of guns | 64 |

Carriages

| | | |
|---|---|---|
| Carriages of different natures for the above guns | | 96 |
| Setts of ſide-arms for ditto | | 96 |
| Mortars | Stone — | 6 |
| | 13 Inch — | 4 |
| | 10 Inch — | 4 |
| | Royal — | 6 |
| | Total of mortars | 20 |
| Beds for the above mortars | | 40 |
| Setts of ſide-arms for ditto | | 40 |

## Spare Arms for Carriages and Side-arms.

| | | |
|---|---|---|
| Wheels with iron ſtreaks for carriages of different calibres | | 36 |
| Iron axle-trees for ditto | | 36 |
| Cheeks for carriages | | 24 |
| Spokes for wheels | | 200 |
| Staves for ſpunges | | 100 |
| Rammers for ditto | | 200 |
| Sheepſkins for ditto | | 100 |
| Wad-hooks | | 12 |
| Plates of copper for ladles | | 60 |
| Copper nails for ditto | lbs. | 20 |
| Iron nails for ſide-arms | ditto | 40 |
| Iron wire | ditto | 20 |

## Shot, Shells, and Grenades.

| | | |
|---|---|---|
| Shot for guns | | 33200 |
| viz. 32 prs. At 900 rounds a gun | 10800 | |
| — 16 — At 600 rounds | 10800 | |
| — 8 — At 600 rounds for each braſs gun and 200 ditto for each iron ditto | 10800 | |
| — 4 — At 200 rounds | 800 | |
| Caſe-ſhot for 32 and 16 prs. | | 2000 |
| Ditto for 4 prs. | | 400 |

## Shells.

| | Number. |
|---|---|
| 13 Inch ſhells at 900 for each mortar | 3600 |
| Ditto to roll from the breach | 1200 |
| 10 Inch ditto at 900 for each mortar | 3600 |
| Royal ditto at 1200 for each mortar | 7200 |
| Hand grenades | 12000 |
| Stones for the ſtone-mortars at 1200 rounds each } cart loads | 1500 |
| 13 Inch fuſes | 5300 |
| 10 Inch ditto | 4000 |
| Royal ditto | 8000 |
| Hand grenade ditto | 14000 |
| Bottoms of wood for ſtone mortars | 8000 |
| Baſkets for ditto | 8000 |

## Machines and their Apparatus.

| | |
|---|---|
| Handſpikes | 600 |
| Large ditto | 40 |
| Long levers with horſes | 10 |
| Quoins | 400 |
| Gins complete | 6 |
| Hand-jacks | 4 |
| Capſtans complete with ropes | 2 |
| Pullies | 6 |
| Skids | 40 |
| Sleighs | 6 |
| Sling-waggons | 3 |
| Limbers | 12 |
| Block-waggons | 6 |
| Common ditto | 30 |

## Cordage.

| | | | |
|---|---|---|---|
| Ropes for guns | | | 10 |
| Spare ropes for gins | | | 6 |
| Ditto for windlaſſes and capſtans | | | 2 |
| Double ſlings | | | 10 |
| | *cwt.* | *qrs.* | *lbs.* |
| Ropes of various ſizes | 18 | — | — |
| Packthread | 1 | — | — |
| | | | *Number.* |
| Drag ropes | | | 50 |

Armoury

## Amoury.

| | Numbers |
|---|---|
| Long wall-pieces | 12 |
| Wall-pieces | 600 |
| Muſquets | 600 |
| Piſtols | 20 |
| Spare rammers for muſquets | 600 |
| Eſpontoons | 400 |
| Scythes with handles | 400 |
| Cuiraſſes with caſques | 50 |

## Ammunition.

| | | | |
|---|---|---|---|
| Flints | | | 40000 |
| Bullets for wall-pieces | | | 3000 |
| | cwt. | qrs. | lbs. |
| Lead for muſquet balls at 20000 rounds a day, including forties | 274 | — | — |
| Match | 109 | — | — |
| | | | Numbers |
| Powder whole barrels | | | 3600 |
| | cwt. | qrs. | lbs. |
| viz. For 10800 rounds from 32 prs. at 10¼ lb. each | 988 | — | — |
| For 10800 rounds from 16 prs. at 5¼ lb. each | 494 | — | — |
| For 10800 rounds from 8 prs. at 3 lb. 4½ oz. each | 316 | — | — |
| For 800 rounds from 4 prs. at 1lb. 10 oz. 4dr. | 11 | — | — |
| For 3600 ditto from 13 inch mortars at 12 lb. 4¼ oz. | 395 | — | — |
| For 1200 ditto to roll upon the breach at 8lb. 3¼ oz. | 69 | — | — |
| For 3600 ditto from 10 inch mortars at 6 lb. 8 oz. 14 dr. | 210 | — | — |
| For 7200 ditto from royal ditto at 3 lb. 4 oz. 7 dr. | 210 | — | — |
| For 7200 ditto from ſtone ditto at 4lb. 1 oz. 9 dr. | 263 | — | — |
| For 12000 hand grenades at 3 oz. 4 dr. | 22 | — | — |

| | cwt. | qrs. | lbs. |
|---|---|---|---|
| For 600000 cartridges for the infantry | 182 | — | — |
| For 3000 cartridges for wall-pieces .... | 300 | — | — |
| For artificial fire-works and combuſtibles | 91 | — | — |
| Add $\frac{1}{15}$ for accidents ..... | 360 | — | — |

## Combuſtibles.

| | Number. |
|---|---|
| Faggots dipped in pitch ..... | 12000 |
| Iron grates for lighting the ramparts to be filled with different combuſtibles ..... | 150 |
| Light balls of the diameter of the ſtone mortars | 400 |
| Carcaſſes ditto ..... | 200 |

| | cwt. | qrs. | lbs. |
|---|---|---|---|
| Port-fire compoſition to be put into the ſhells | 54 | — | — |

## Articles of different kinds.

| | Number. |
|---|---|
| Oaken planks for platforms ..... | 1000 |
| Sleepers for ditto ..... | 500 |
| Ballaſt-baſkets ..... | 1000 |
| Hand barrows ..... | 100 |
| Spare helves for intrenching tools ..... | 2000 |
| Sand bags ..... | 20000 |
| Large oil-cloths ..... | 100 |
| Small ditto ..... | 100 |

| | cwt. | qrs. | lbs. |
|---|---|---|---|
| Greaſe ..... | 36 | — | — |
| Flannel for cartridges ..... | yards | | 300 |

## Iron-work and Nails.

| | cwt. | qrs. | lbs. |
|---|---|---|---|
| Iron-work of ſorts for gun carriages and mortar beds ..... | 36 | — | — |
| Iron-plate for carriages, round, ſquare and flat ..... | 27 | — | — |
| Nails for wheels ..... | 9 | — | — |
| Ditto for platforms ..... | 18 | — | — |
| Ditto 40 to the lb. ..... | 3 | — | — |
| Iron wire ..... | 3 | — | — |
| Steel ..... | 9 | — | — |

Articles

Articles for the Laboratory for making up Compoſitions of various kinds.

Powder; pulverized ſaltpetre; flowered-ſulphur; powdered charcoal; crude antimony; roſin; tar; pitch; turpentine; ſpirits; ſpirits of wine rectified; oil of olives and lintſeed; vinegar; yellow wax; ſuet; greaſe; aſſa-fœtida; glue; thread; fine and coarſe tow; linen and cotton cloth and barras; ſewing thread; old linen and match; faggots; iron wire; thin cord; ſmall iron chambers and piſtols for the carcaſes. The quantity of theſe articles depends on the number and kind of fire-works, and the nature of the compoſitions, which may be eaſily known from the laboratory books.

Articles for the Laboratory for making up Fire-works.

| | *Number* |
|---|---|
| Cheſt of drawers | 1 |
| Steel-yard | 1 |
| Balance with ſcales | 1 |
| Tables | 3 |
| Ditto for mealing powder and mixing compoſitions | 2 |
| Large copper cauldrons | 3 |
| Medium and ſmall ditto | 5 |
| Iron trivets for ditto | 6 |
| Large peſtle and mortar of bronze | 1 |
| Common hammers | 3 |
| Pincers ..... pairs | 3 |
| Large and ſmall axes | 3 |
| Raſps for wood | 10 |
| Files | 10 |
| Drawing knives | 10 |
| Common ditto | 6 |
| Large and ſmall ſciſſars ..... pairs | 6 |
| Iron punches | 10 |
| Straight and crooked awls | 10 |
| Packing needles | 12 |
| Sewing ditto | 100 |
| Common and fine ſaws | 8 |
| Augres and gimblets | 30 |
| Common ſieves | 6 |
| Fine ſilk ditto | 3 |

| | Number. |
|---|---|
| Small wooden bowls for holding compoſitions | 10 |
| Benches for driving fuſes | 10 |
| Drifts for ditto | 24 |
| Tin funnels of ſizes | 10 |
| Tin meaſures ditto | 50 |
| Wooden ſetters for fuſes | 10 |
| Small ditto | 20 |
| Oaken planks with holes for loading the hand grenades and fuſes | 1 |
| Bench with 2 beaks, one of iron and one of wood | 1 |
| Benches for tying up the fire pots, &c. | 3 |
| Lanterns ordinary and dark | 50 |
| Eprouvettes for powder | 1 |
| Can-hooks | 60 |
| Quadrants | 30 |
| Priming wires | 500 |
| Copper ladles | 2 |
| Large buckets | 4 |
| Pails | 6 |
| Braſs ſcales | 2 |
| Wooden ditto | 12 |
| Large and ſmall oil cloths | 20 |
| Common compaſſes pairs | 4 |
| Calibres pairs | 2 |
| Glue bruſhes | 12 |
| Royal and common paper reams | 10 |
| Paſteboard ditto | 2 |
| Flints, ſteels, tinder-box and matches | |

| | cwt. | qrs. | lbs. |
|---|---|---|---|
| Tacks and large nails | 1 | — | — |
| Wax candles | 3 | — | — |

## Intrenching Tools.

| | Number. |
|---|---|
| Pick-axes | 1000 |
| Mattocks | 1500 |
| Shovels | 400 |
| Large and ſmall axes | 200 |
| Hand bills | 500 |

Tools

## Tools for 12 Carpenters.

| | Number. |
|---|---|
| Broad axes | 12 |
| Small ditto | 12 |
| Croſs-cut ſaws | 4 |
| Common ditto of ſorts | 12 |
| Triangular files for ſaws | 24 |
| Planes | 30 |
| Mortaiſe chiſſels | 24 |
| Hatchets | 12 |
| Square and round gouges | 16 |
| Chiſſels of ſizes | 36 |
| Large and ſmall compaſſes | 8 |
| Large gimblets | 16 |
| Small ditto | 80 |
| Drawing knives | 12 |
| Sledge hammers | 4 |
| Pincers pairs | 12 |
| Whetſtones | 4 |
| Hand-vices | 8 |
| Iron crows | 4 |
| Working benches | 8 |

## Tools for 6 Blackſmiths.

| | |
|---|---|
| Large bellows with anvils and ſtocks | 2 |
| Forge tongs pairs | 16 |
| Nail borers | 6 |
| Forge hammers | 12 |
| Sledge ditto | 6 |
| Files of ſizes | 24 |
| Benches with beak irons, one large one ſmall | 4 |
| Small vices | 6 |
| Small anvils | 4 |
| Iron preſs for binding and ſtreaking wheels | 1 |

## Tools for 12 Armourers.

| | |
|---|---|
| Forge bellows | 4 |
| Anvils with ſtocks | 4 |
| Small anvils | 6 |

| | Number. |
|---|---|
| Forge hammers of ſizes | 24 |
| Forge tongs pairs | 16 |
| Benches with iron and wooden beaks | 12 |
| Files of ſizes | 200 |
| Raſps | 50 |
| Planes | 24 |
| Large and ſmall gouges | 48 |
| Inſtruments for making ſcrews of ſizes | 16 |
| Drills with bows | 12 |
| Augres | 12 |
| Gimblets | 60 |
| Drawing knives | 12 |
| Hand vices | 12 |

With a proper quantity of coals for the black-ſmith and armourers.

If the place be countermined, there ſhould be the ſame proportion of miner's tools as in the former inventory; taking care to increaſe the number of them in proportion to the number of miners, and to add the following articles. Oaken planks for mantlets; beams of 5 inches by 7; planks for occaſional works, and for boxes to contain the powder; beams for making the frames of the occaſional works; pitched wooden troughs; ſauciſſons made of coarſe cloth; large oil-cloths; ſand-bags; petards of ſizes; ſhells; piſtols; blunderbuſſes; tin chandeliers. Lanterns; olive-oil; candles; nails of 40 to the lb.; powder; clay; old dung; inflammable and fetid compoſitions. The quantity of each of theſe articles muſt be apportioned to the manner in which the mines are charged, and to the method of carrying on the ſubterranean war, which will be enlarged on in the 4th chapter.

126. The number of artillery-men for the daily ſervice of the guns and mortars contained in this inventory, may be eaſily inferred from the former remarks on that ſubject (57): three times that number will be the proper compliment for the defence of the place; one part is on duty on the batteries, and the ſecond is preparing and providing the batteries with ſtores, while the third is repoſing. If the corps of artillery be not ſufficiently numerous for all theſe duties, the line muſt furniſh a certain number of additional gunners: four men at leaſt, ſhould be attached to every piece of

of ordnance; ſo that if there be 60 guns and 20 mortars in the place, there ought to be 320 artillery-men, beſides ſerjeants, &c. To every piece of ordnance there ſhould be a ſkilful expert man to direct the loading and laying, and the additional gunners ſhould be allowed for in the demand of troops made for the garriſon. Beſide the commanding officer of artillery, there ſhould be 5 or 6 others of inferior rank; and even more, if the place be capable of making a long defence.

The number of carpenters, black-ſmiths, and armourers will be regulated by the proportion of tools in the preceding inventory; part of them may be taken from the artillery, the reſt from the infantry of the garriſon, or the inhabitants of the place.

With one ſtage of countermines, and a large gallery, where it is poſſible that the miners on both ſides may meet, their number ſhould be 200; and 300, when there are two ſtages of countermines, with two officers, and two non-commiſſioned officers: part to be taken from the miners belonging to the artillery, the remainder from the garriſon; taking care that the latter are men of approved courage and fidelity.

## CHAP. II.

### Of the first Disposition to be made for the Defence of a Fortress N N.

127. THE magazines being furniſhed with the ordnance, ammunition and ſtores contained in the inventory; every article depoſited in the place allotted for it in the diſtribution; the projected works completed, and the countermines prepared; the commanding officer of artillery on the apprehenſion of a ſiege, makes under the orders of the governor his diſpoſitions for defence: diſtinguiſhing the operations neceſſary to be performed previous to the inveſtiture, from thoſe that may be deferred till the place is inveſted.

128. In the firſt place, the muſquet cartridges are made up; light-balls, pitched faggots, and fire-pots prepared; the fuſes drove; a certain number of ſhells filled; and in ſhort, every thing in the laboratory put in ſuch a ſtate of forwardneſs, that in caſe of an attack, nothing will remain to be done

done but to fill the reſt of the ſhells and grenades; and make up combuſtibles as faſt as they are wanted. All the guns are mounted; part on the moſt attackable fronts, the reſt on the barbette-batteries: each of which ſhould be ſpacious enough to contain ſeveral guns, the better to command the adjacent country; and the governor directs the engineers to cut out the embrazures in the flanks.

If the place be countermined; a quantity of well ſifted earth is laid in different parts of the galleries, and frames and planks prepared for carrying on freſh branches: an exact plan and profile of the countermines are taken, which ſhould be very carefully preſerved; and the miners drive ſmall ſhafts on every ſide to determine the nature of the ground, with a view of aſcertaining the time requiſite for making an excavation of a cubical foot; and judging how far the ſound of the enemy's miners at work can be heard; which entirely depends on the tenacity of the ſoil: that nothing, in a word, may be wanting to render the ſubterranean operations conducive to ſucceſs; experiments are made, to determine the line of leaſt reſiſtance for a chamber, made between the ſurface of the ground and an excavation 9 feet below it (which is the depth of the work that the beſieger ſhould carry on in ſearching for the countermines) and to aſcertain the charge for only ſhaking the earth, and burying the enemy's batteries without making a large *entonnoir*. The care of the miners is intruſted to an intelligent officer; ſome men are occaſionally picked out from the infantry for that ſervice. The carpenters, blackſmiths, and armourers ſhops are fixed, that they may prepare the ſeveral articles belonging to them; and ſome horſes and oxen procured for removing the guns and ſtores to any part where they may be wanted, with a ſufficient quantity of forage for their uſe.

As œconomy in the daily iſſues of ſtores, and in the extra-pay to the artillery-men and additional gunners is a matter of great moment; a commiſſary and ſome clerks of ſtores are appointed to keep an account of all iſſues and expenditures, that exact returns of every thing may be made out when called for.

129. At the ſecond epoch (127) viz. when the place is inveſted; the commanding officer of artillery directs the powder and every other article that will be wanted during the ſiege, to be diſtributed in the different magazines; and the

the ſhells and grenades to be filled and depoſited in ſecure places: this ſhould be done before the enemy opens his batteries. The amuzettes or wall-pieces with their ammunition are carried to the advanced works, particularly on the ſide where the enemy is breaking ground; and the barbette batteries furniſhed with powder and ſhot, and a detachment of men for firing at the parties of the enemy that advance to reconnoitre the works, or drive in the out-poſts of the garriſon: the officer charged with this duty, after receiving directions from the governor with reſpect to the parties detached from the garriſon, ſhould remain on the batteries during the whole day, to ſeize every opportunity of annoying the enemy.

An officer of the civil branch is appointed to aſſiſt the ſtore-keeper, through whoſe hands all iſſues of ſtores muſt paſs, as he is beſt acquainted where each article is depoſited; this officer is intruſted with the key of the magazine, whence the daily iſſues of powder are made: the keys of the other magazines remain according to cuſtom with the governor and ſtore-keeper.

It may be neceſſary during the ſiege to project ſhot and ſhells to different diſtances according to the ſituation of the beſieger's park or powder magazines; the following table therefore ſhews the ranges of guns and mortars: the charges are ſuppoſed to be $\frac{2}{7}$ of the weight of the ball for muſquets, &c. $\frac{1}{4}$ of the weight of the ſhot for 4 and 8 prs.; and $\frac{1}{8}$ for 16 and 32 prs. The chambers of the mortars are elliptical, and filled with powder; thoſe of the ſtone-mortars are in form of a troncated cone.

Point

| | | Point Blank. Yards. | Longeſt Range. Yards. |
|---|---|---|---|
| Muſquet | | 270 | 1348 |
| Wall-piece | | 303 | 1550 |
| Long wall-pieces | | 438 | 2360 |
| Guns | 4 pr. | 438 | 3035 |
| | 8 | 540 | 3372 |
| | 16 | | 3541 |
| | 32 | | 4046 |
| Mortars | Royal | | 1348 |
| | 10 inch | | 1686 |
| | 13 ditto | | 2192 |
| | 17 ditto | | 2697 |
| | Stone | | 337 |

## CHAP. III.

### Of the Diſpoſitions for the actual Defence.

130. WHEN it is known either from the previous diſpoſitions of the enemy, or from his breaking ground, which front he intends to attack; the commanding officer of artillery directs the guns allotted for that front to be drawn to it; placing thoſe of the ſame calibre together, to avoid the confuſion ariſing from mixing the ſhot; and makes the carpenters lay down the platforms for the guns in the flanks. The engineers conſtruct in the works of the front attacked, occaſional magazines for containing the powder and cartridges for one day's expenditure. The infantry furniſh the neceſſary number of additionals to aſſiſt in working the guns; the ſame men ſhould be always attached to this duty, to ſave the trouble of inſtructing every day a freſh ſet, and ſhould be under the care of their own non-commiſſioned officers.

The commanding officer of artillery then makes out a plan of defence as far as reſpects the artillery, which he ſubmits to the governor for his approbation; and afterwards communicates it to the ſeveral officers under him, that being acquainted with the principles on which the defence is to be conducted,

conducted, they may do their utmoſt to contribute to its ſucceſs.

131. In this plan, the firſt axiom is *to retard as much as poſſible the progreſs of the beſieger, and to multiply his dangers and difficulties:* this is effected *by a judicious application of fire-arms, ſallies, and countermines.* The whole front of the attack is lighted during the night, that the artilleriſts may direct their guns with greater preciſion, and diſcover the movements of the enemy; which will enable the governor to judge when and on what ſide, a ſally may be made or a mine ſprung, to the greateſt advantage.

132. At the beginning of the ſiege the garriſon throw ſhells filled with combuſtibles to light the front of the attack during the night: when the enemy is advanced within 350 yards of the works, light balls are uſed for this purpoſe; and when he approaches the covered way, pitched faggots are thrown on the glacis to diſcover his works: and, finally, faggots and grates filled with combuſtibles are placed on the parapets of the advanced works, whenever the enemy is endeavouring to effect a lodgment.

133. It is an eſtabliſhed maxim in making ſallies, that they be ſupported by a heavy fire of artillery and muſquetry, diſpoſed in the moſt advantageous parts of the works for compelling the beſieger to remain within the trenches, or expoſing him to great loſs if he advance to repel the attack: wherefore the ſally ought to be previouſly concerted with the commanding officer of artillery, who ſhould ſuggeſt any method that occurs to him of rendering the fire of the artillery more effectual in covering it.

134. The ſervice of the countermines will be diſcuſſed in the ſubſequent chapters; at preſent we ſhall enter into a detail of the other diſpoſitions for defence (131). When the beſieger begins to break ground, the proper detachments are ſent to the barbette-batteries, with injunctions to let the additional gunners aſſiſt in working the guns, that they may become expert: this party, and all others on the different batteries during the ſiege, are relieved every 24 hours. The fire from theſe batteries is directed during the day either againſt the unfiniſhed parts of the trenches, or to enfilade the communications; as may appear moſt advantageous. In the evening, precautions are taken that the guns may bear during the night on the part moſt likely to diſtreſs

diſtreſs the enemy; ſhells filled with combuſtibles are from time to time projected to light the country (132).

135. When the ſituation of the enemy's firſt batteries is known, the embrazures on the faces of the baſtions and the other works oppoſed to the attack are opened, and the platforms laid; this ſhould be completed in 24 hours. The direction of ſome of the embrazures ought, in conformity to the eſtabliſhed axiom (131), to be towards the ground on which the enemy muſt carry on his ſap; the others againſt the batteries, oppoſed to the guns that fire upon the head of the ſap: it would be a manifeſt departure from this principle, to oppoſe gun to gun without regarding the ſap; and the error would be ſtill greater, to fire againſt works that are already completed, and conſequently proof to cannon-ſhot. The commanding officer of artillery points out the objects againſt which the fire is to be directed, enjoins the moſt exact attention in loading and laying the guns, and forbids them to be altered. He goes round the attack at leaſt 3 times every 24 hours; early in the morning, to reconnoitre the enemy's works, and alter the direction of the guns, if neceſſary; in the afternoon, to take memorandums of what ammunition may be wanted; and in the evening to point out where the light-balls are to be thrown, and ſee that the fire both of artillery and muſquetry is directed againſt the unfiniſhed parts of the enemy's works.

136. When the batteries are mounted with cannon, the guns are withdrawn early in the morning from the barbette batteries, and brought back at night to enfilade the communications: this manœuvre is continued till the enemy's muſquetry is advanced too cloſe to the works. The 10 inch and royal mortar batteries are opened, as ſoon as the beſieger advances his communications between the ſecond parallel and the place: theſe mortars ſhould be placed in ſuch a ſituation that, in ſpite of the inevitable irregularity of the ranges, the ſhells may fall on ſome part of the approaches. During the night, light-balls are projected to aſſiſt the direction of the cannon and muſquetry. When the approaches are advanced within 300 yards of the covered way, the ſtone-mortars come into uſe; they are planted in the ſaliant angles of the covered way, againſt which the enemy is directing his approaches. All the mortars fire day and night: when the third parallel is nearly finiſhed, the ſtone-mortars are withdrawn from the covered way,

way; and placed in the works immediately in the rear, at the foot of the barbette batteries, to fire into the enemy's lodgments on the creſt of the glacis, when the garriſon is obliged to evacuate the covered way.

While the beſieger is working at the third parallel, great number of pitched faggots are thrown upon the glacis during the night from the covered way: the guns that enfilade the glacis are directed againſt the lodgements on the creſt of it; and every embrazure that flanks the enemy's approaches is furniſhed with cannon.

137. The third parallel being completed, the enemy's diſpoſitions ſhould be carefully obſerved to judge whether he meditates an attack on the covered way by ſtorm or ſap; if the former appears to be his intention, the guns that enfilade the creſt of the glacis and the covered way, ſhould be furniſhed with flannel cartridges for quick firing, and ſome rounds of caſe or grape-ſhot; and the men attached to them inſtructed how to conduct themſelves in caſe of an aſſault: at the cloſe of day, quantities of pitched faggots ſhould be thrown on the glacis, and the fire-grates lighted in the ſaliant angles of the moſt expoſed works.

When the enemy has gained the creſt of the glacis, round ſhot ſhould be fired from all the guns that enfilade it, till the garriſon is compelled to abandon the covered way; then caſe-ſhot ſhould be fired: the mortars ſhould keep up an inceſſant fire on the returns of the ſaliant angles of the glacis, where the beſieger muſt eſtabliſh his communications.

The garriſon will rally in the places of arms and the ditch, and endeavour to regain poſſeſſion of the poſts they have loſt; the fire from the ſtone-mortars ſhould ceaſe the inſtant the troops are in motion for that purpoſe, and the cannonade re-commence.

In all aſſaults, the officers of artillery ſhould be ſtationed in the works that contribute moſt to the defence, with directions how to act on every emergency: their commanding officer ſhould take up his ſtation at the point of the greateſt importance.

138. When the beſieger has gained the creſt of the glacis by ſap, all the mortars ſhould play on the communications that will be made along the faces; and while the ſap is carrying on, it ſhould be enfiladed by the guns and mortars that bear on it. If the guns in any of the attacked works can plunge into the enemy's lodgments on the glacis, ſome embrazures

embrazures ſhould be repaired: throwing light-balls during the whole night, that the firing may be the more exact and effectual. The ſame diſpoſitions ſhould be continued, while the enemy is conſtructing and firing from the batteries in breach; and be ſupported by a continual fire of muſquetry, directed againſt the embrazures of the batteries.

139. The beſieger having completed his deſcent into the ditch, and begun epaulments to cover his approach to the foot of the breach, every poſſible exertion ſhould be made to retard his progreſs: the guns ſhould fire inceſſantly againſt the epaulments with round ſhot; ſhowers of ſhells, and hand-grenades be thrown from every part; and when the enemy has gained the foot of the breach, the largeſt ſhells ſhould be ſet fire to and rolled down.

Theſe diſpoſitions intended for the out-works will be ſtill more effectual from the body of the place, where the fire from the flanks that defend the breach is greatly ſuperior to the enemy's: ſince, beſide this flanking fire againſt the epaulments, a heavy fire can be alſo directed againſt the counter-battery.

A breach having been made in any of the out-works, the artillery ſhould be withdrawn in time, and placed in ſome work in the rear of the one that is diſmantled, in order to fire into it. When the guns are withdrawn from the ravelin, ſome embrazures ſhould be opened in the curtain, that the beſieger may be expoſed to a heavy fire from many points at once, the inſtant he attempts to lodge himſelf in the ravelin.

140. The breach being rendered practicable, a great number of burning faſcines and light balls ſhould be thrown into it; and over theſe dry faggots and combuſtibles of all kinds: when this expedient is exhauſted, all the guns and mortars ſhould be pointed at the breach, to mow down the enemy's column in mounting to the aſſault.

From the different methods of repelling aſſaults explained in the ſecond book of Military Architecture, the officers of artillery will ſee in what manner the defence of a fortreſs provided with ſtores of all kinds, may be protected by their ſkillful and judicious conduct, combined with the exertions of the other parts of the garriſon.

Though the preceding regulations may ſeem to be adapted only to places where the works mutually ſupport and command each other, and every point in the environs; yet they

they are equally applicable to fortreſſes ſituated on mountains with different profiles: provided that in the proportion of ſtores, an additional number of mortars and combuſtibles be allowed for the defence of the dead angles, which frequently occur in places in ſuch ſituations; and the weak points be carefully diſtinguiſhed from thoſe that are inacceſſible, even when a breach is effected.

141. When at length, the place is no longer defenſible, the chamade is beat: at the ſurrender the commanding officer of artillery in terms of the capitulation, will give the enemy an exact inventory of the ordnance and ſtores. If permiſſion be granted to take out any covered waggons, the largeſt guns ſhould be carried out on block waggons covered with oil-cloths, and not inſerted in the inventory given to the enemy. But if the ſiege be raiſed, all the ſtores liable to be pillaged ſhould be immediately carried back to the magazines, and a general inventory taken, diſtinguiſhing the ſerviceable from the unſerviceable; the guns and mortars ſhould be alſo examined, and thoſe that are damaged ſent to the foundery.

## CHAP. IV.

### Of the Defence of the Countermines.

142. IN the greater part of ſieges, the beſieger has a decided advantage; for the environs of moſt places being ſufficiently ſpacious, it is in his power to plant a very numerous artillery in his firſt batteries, and eſtabliſh a fire ſuperior to that of the place: but in the attack of a fortreſs where the countermines are judiciouſly diſpoſed, the garriſon at the inſtant the beſieger is endeavouring to lodge himſelf on the glacis, and in the other works regains their ſuperiority; ſince he is under the neceſſity of feeling his way with much danger and loſs of time, in order to aſcertain the ſafety of his lodgements and batteries; without knowing the points where the beſieger awaits him, and often finding himſelf buried in his own works at the moment he leaſts expects it.

143. To oppoſe the beſieger effectually in his reſearch for the countermines requires much diſcernment, an uninterrupted vigilance, and great exertions of bravery. The fun-

damental maxim is *to anticipate the attempts of the enemy, and to reſerve as long as poſſible the countermines deſigned for blowing up the principal lodgements, and the batteries in breach.* For this purpoſe;

1. The proviſional branches ſhould be completed by the time that the beſieger reaches the foot of the glacis.

2. The enemy's miners ſhould never be allowed to get below the countermines, ſince in this warfare whoever has loweſt ground has the advantage.

3. Every attempt ſhould be made with fougaſſes and petards to deſtroy the enemy's works at a diſtance from the permanent countermines.

4. The charges for ruining the enemy's works ſhould be calculated to produce the deſired effect without running any riſque of damaging the permanent countermines.

5. When to fruſtrate the enemy's attempts, it is neceſſary to ſpring a mine at a point, that may interrupt the communication with ſome of the permanent countermines; a freſh communication ſhould be immediately made from the branches, or the neareſt galleries.

6. Proviſional branches for feeling for the enemy will be moſt effectual, when made to the right and left at the ſame time.

144. To convey a general idea of this ſubterranean war, let us ſuppoſe a place with two ſtages of countermines; that permanent and proviſional works are prepared along the front of the attack, when the beſieger gains the foot of the glacis; and that the ſoil has depth and tenacity enough to enable the beſieger to execute any work he may judge neceſſary. The objects of the beſieger being to render uſeleſs the countermines of the place, in order to ſecure his principal lodgements and batteries in breach, he will be obliged either to attack them in front by the means of ſlopes and galleries; or to attack the paſſages leading to them by ſinking ſhafts in the covered way (Part I. Chap. VII.): the following are the diſpoſitions for oppoſing theſe attempts.

145. The front that the enemy intends to attack being at length known, a larger quantity of earth is carried into the galleries on that ſide: and when he approaches the foot of the glacis, filled ſand-bags are ranged along the galleries without obſtructing the paſſage, and a large quantity of dung laid in the ditch near the entrance of the countermines. A miner

miner is poſted in every three or four branches that point towards the enemy to liſten whether he be at work: on hearing him, the miner ſhould keep ſtrict ſilence, and redouble his attention to aſcertain exactly the ſituation, diſtance and nature of the work he is carrying on. If the enemy in making his lodgments meet with one of the ventilators of the mines, the bottom ſhould be immediately cloſed with a ſand-bag, and the ſpace between the bottom of the gallery and the ventilator filled up very ſolidly. When from the nature of the ſoil the enemy can drive his ſhafts under ground without being heard, a well braced drum ſhould be placed at the ſuſpected points with ſome grains of ſand on the parchment, which will move when the ground is ſtirred or ſhaken.

Having aſcertained by one of theſe methods that the enemy is advancing towards the countermines, the five following caſes may occur.

1. His ſhaft may fall on one of the branches of the firſt ſtage.

2. Or on a gallery of the firſt ſtage.

3. It may approach very near to a branch or gallery of the firſt ſtage.

4. It may fall on a branch or gallery of the ſecond ſtage.

5. It may fall obliquely on the countermines of the ſecond ſtage, without the beſieger being overheard in working from the countermines of the firſt ſtage.

146. The general method of oppoſing above ground theſe attempts of the beſieger is to throw ſhells into the ſhafts; the ſituation of which is eaſily diſcovered by the ſoil of the excavation: the exploſion of a ſhell falling into a ſhaft, renders all further attempts for ſome time impracticable.

Another method equally effectual is to make a ſally, and throw into the ſubterranean works of the beſieger combuſtibles of a very fetid nature, to render the air unfit for reſpiration. Beſide this, the following oppoſition is made underground.

147. Should a ſhaft fall on a branch of the firſt ſtage (145, No. 1), it ſhould be immediately filled with ſand-bags preſſed cloſe together for the ſpace of 20 feet; in the middle of this ſpace immediately under the ſhaft 4 or 5 loaded ſhells ſhould be laid with the fuſes of ſuch a length that they may all burſt together: they are ſet fire to by a ſauciſſon the moment the beſieger gains the roof of the branch, and by

their explosion destroy the shaft and loosen the soil, so that the besieger will be unable to renew his work without great trouble and loss of time.

In a tenacious soil, a hole about 4 feet square may be made by taking some bricks out of the roof of the branch at the part where the shells are lodged, and supporting the earth with planks; the explosion of the shells will do more injury to the shaft and less to the branch.

When the shaft falls near the extremity of a branch, a box containing about 1 cwt. of powder may be placed close to it, the branch filled with sand-bags and dung for the space of 10 feet, and a saucisson laid in a wooden trough to set fire to the powder, the moment the besieger reaches the roof of the branch.

148. In the second case, viz. of a shaft falling on a gallery of the first stage leading to the advanced countermines; some strong trestles equal in length to the width of the gallery, and about $3\frac{1}{2}$ feet high should be instantly placed under the shaft across the gallery, and at the distance of 5 or 6 feet from each other; and upon these should be laid a floor of planks 20 feet long, and the space between them and the roof filled with sand-bags: 4 or 5 large shells should be then placed on this floor, disposed as in the preceding paragraph, and set fire to the moment the besieger reaches the roof of the gallery. As by this method, the communication is kept open below the trestles, it is preferable to the other of filling the whole space with sand-bags. Beside, if the countermines to which the gallery leads be of great importance, a fresh communication may be made from the nearest branches or galleries, after the explosion of the shells.

The besieged should perform these operations as silently as possible; not using hammers to knock out the bricks or make holes in the roof, but forcing them out with levers, that the besieger may not be aware of his danger. But the operations of the besieged will not fail to be discovered in the three following circumstances.

149. When the shaft passes near a branch or gallery of the first stage (145, No. 3,); its direction and distance being known, the besieged should ascertain whether the shaft when sunk till it meets with water or rock will be near enough to any of the permanent countermines to destroy them: If that be the case, he should carry on horizontal branches on both sides to find out the shaft, and have every thing in readiness for

for charging a chamber inſtantly to deſtroy it. As the beſieger muſt be aware of this, the beſieged ſhould attentively liſten to find out when he ceaſes to work, which will be a ſign that he is charging his chamber; taking care to diſtinguiſh between the ſound that is made in hollowing out the earth, and a noiſe frequently made to counterfeit it, in order to deceive the beſieged.

When the beſieger ceaſes to work, the diſtance between the branch and the ſhaft ſhould be compared with the diſtance between the bottom of the ſhaft and the ſurface of the ground; and if the line of leaſt reſiſtance be towards the ſurface, it it will be ſufficient to make a noiſe ſimilar to that of removing earth, without proceeding any farther: which will make the beſieger believe that the work is always going on, and induce him to ſpring his mine without doing any detriment to the countermines, yet greatly to his own diſadvantage; ſince after the exploſion the ground will be unfavourable to any future work. But if the line of leaſt reſiſtance be on the ſide of the branch, a chamber ſhould be inſtantly charged with a proper quantity of powder and ſprung. If the beſieger, notwithſtanding, continues his work, the branch ſhould be advanced within 7 or 8 feet of the ſhaft, that it may effectually deſtroy it, without doing any damage to the countermines (143).

150. In the fourth caſe, viz. of the ſhaft falling on a branch or gallery of the lower ſtage, the beſieged will make the ſame diſpoſitions as before (147, 148), and ſet fire to the ſhells the inſtant the beſieger reaches the roof of the gallery; when the ſhaft paſſes near any of the countermines of the firſt ſtage, the beſieged will carry on horizontal branches as directed in the preceding paragraph, making at the ſame time the neceſſary diſpoſition in the countermines of the lower ſtage, that are threatened by the enemy.

When the ſhaft without paſſing near the countermines of the firſt ſtage falls obliquely on thoſe of the ſecond, horizontal branches ſhould be carried on from the lower ſtage in the ſame manner as directed for the upper one.

151. The ſubterranean war is ſtill more in favour of the beſieged, when the beſieger attacks the countermines in front by the means of galleries or branches; ſince the former will be then enabled to diſpute the ground inch by inch. When the enemy's gallery points towards a proviſional branch, he ſhould be waited for in ſilence, till arrived at a proper diſ-

tance, and a mine ſprung to deſtroy his works (147). But if he advance on a permanent branch at a diſtance from the proviſional ones, the neareſt proviſional branch ought to be carried forward to meet him as before directed.

152. It may happen either through the negligence of the beſieged, from the nature of the ground, or the inſtruments uſed in boring it, that the beſieger may without being heard gain the wall of the countermines: in this caſe, a large petard well propped behind ſhould be inſtantly fixed againſt the part he is approaching, and the ſcrews that faſten it to the plank taken out, that it may act againſt the wall with greater force and do the enemy more damage: as ſoon after the exploſion as the ſmoke will permit, the miners ſhould examine if any communication be opened between the countermine and the enemy's works; throw in quantities of fetid combuſtibles; cloſe the hole hermetically, to prevent the ſtench from paſſing into the countermines; and block up at the ſame time all acceſs to the beſieger.

Should the beſieger gain an entrance into any of the countermines, ſome of the moſt reſolute miners armed with cuiraſſes and blunderbuſſes ſhould be ſent to drive them as far back as poſſible, and the communication be interrupted and blocked up with ſand-bags; all ſorts of combuſtibles ſhould be thrown into the intercepted part to compel the enemy to abandon it.

153. The garriſon ſhould never relax in oppoſing the deſigns of the enemy, even though all the permanent countermines are by degrees deſtroyed and they are thus deprived of the means of blowing up the enemy's batteries; ſince the defence of the place will be thereby conſiderably protracted: Whereas ſhould they under the idea of preſerving the permanent works entire, be too cautious in counteracting the beſieger, he may by carrying on his enterprizes under ground, render all the countermines uſeleſs; and deprive the garriſon of every benefit that could reſult from them.

After ſpringing a mine, the miners ſhould never be too haſty in removing the earth or rubbiſh that chokes up the paſſage to it, or in examining its effects; this reſearch being attended with no utility, and moreover, very dangerous: the ſmell and ſmoke ſhould be drawn away, and the air purified by placing mantlets at the entrance into the countermines, with tin pipes fixed in them and communicating with the place where the mine was ſprung. The miners in the mean

mean time ſhould be liſtening in the other branches to diſcover the enemy's operations.

154. The ſame directions are to be obſerved, in defending the countermines under the ditch, in the out-works and in the body of the place.

Theſe operations ſhould be always ſupported by the ſallies of ſmall parties, made unexpectedly in the ditch, to kill the enemy's miners, and throw fetid combuſtibles into their works.

From the method of attacking countermines, treated of in the firſt part, it will be eaſy to aſcertain whether the proviſional works, in either of the three caſes mentioned at the end of the third book of military architecture, are properly combined: if not, the defect may be eaſily remedied, in making out the proportion of ſtores for the place.

## PART V.

### Of the Use of Permanent Countermines in the Defence of Places.

155. FOUGASSES and permanent countermines being intended to overturn the principal lodgments and batteries of the beſieger, the following is the mode of attaining this object. When the beſieger begins to make the third parallel, all the fougaſſes on the front of the attack are charged with the quantity of powder found by experiment (128) to be adequate to the line of leaſt reſiſtance; the fauciſſons of communication are laid in pitched wooden troughs ſunk in the ground about a foot deep along the palliſadoes, that, if the enemy attempt to carry the covered-way by aſſault, he may not be able to cut them off. Theſe communications begin at the ſaliant angles of the covered-way, and terminate at the re-entering angles of the places of arms; they are ſo diſpoſed, that the fougaſſes at the moſt ſaliant angles may be ſprung ſeparately; then thoſe before the faces of the baſtions and ravelins; and laſtly thoſe in the faces of the places of arms: The fauciſſons ought to be frequently changed when there is reaſon to apprehend that they may be injured by the humidity of the ground.

156. Then, the covered-way being ſtormed, and the garriſon forced to abandon the ſaliant angles and retire into

the places of arms; it will be a matter of conſideration, (as the number and diſpoſition of the enemy will be diſcovered by means of light balls, &c.) whether it will be more adviſeable inſtantly to ſpring the fougaſſes, or wait till their lodgments are completed: This muſt depend on the garriſon, and the circumſtances of the ſiege. Suppoſing the attack to be ſo vigorous that the garriſon is compelled entirely to abandon the covered-way, a ſtrong detachment ſhould under cover of a heavy fire from all the works that command the places of arms force their way into them again, and ſet fire to the ſauciſſons that lead to the fougaſſes; and immediately after the exploſion, retire to their former poſt, and pour in a very heavy fire of muſquetry.

157. If the beſieger attempt to get poſſeſſion of the covered way by ſap, the fougaſſes ſhould be ſprung ſucceſſively, accordingly as he makes his lodgments; taking care to ſpring them before the enemy can diſcover and render them uſeleſs.

158. The beſieger having re-eſtabliſhed his lodgments on the creſt of the glacis, and begun to conſtruct his batteries in breach, the chambers of the countermines of the firſt ſtage beneath the batteries are charged: the quantity of powder ſhould not be too great for the following reaſons.

1. Leſt the beſieger lodge himſelf in the excavation or *entonnoir*; the ground ſhould only be ſhaken enough to overſet the batteries and bury the guns.

2. Not to damage the contiguous countermines by too violent an exploſion; which might render them of no effect in oppoſing the enemy in making his deſcent into the ditch.

3. Not uſeleſsly to expend powder, which may before the concluſion of the ſiege be wanted for ſome eſſential purpoſe.

159. That the charge may act only on the ſide of the line of leaſt reſiſtance, the paſſage to the chamber ſhould be very ſolidly filled up for a length and half of the line of leaſt reſiſtance. For example, ſuppoſe the chambers A, B, (Pl. 5, Fig. 9) are to be charged, and each branch C D, E F, be equal to the line of leaſt reſiſtance: in A C D, B E F, lay a layer of dung 4 or 5 inches deep, and place in each chamber a well-pitched wooden box of the proper ſize to contain the powder: having filled it and applied the ſauciſſon, cover it with planks; and in caſe of damp with oil-cloth.

Then

Then having filled the ſpace between the box and the ſides of the chamber with dung, large ſtones and clay; cloſe the mouth of it with planks and mantlets, placed along the walls C D, G H, E F, K L, ſupported by the horizontal beams M, N, ſecured by ſtrong wedges, and fill all the interſtices with ſand-bags and dung. Continue this operation to D, F, where apply other planks ſupported as before by the horizontal beams P; fill up the interſtices with dung, &c. as far as Q, ſo that the right lines A Q, B Q be each a length and half of the line of leaſt reſiſtance: at Q place ſome planks firmly ſupported by the beams R fixed in the wall S. The fauciſſon ſhould be conducted in a pitched trough along the branches C D, E F, ſo that that the two chambers A, B may be ſprung at the ſame inſtant: for it is evident, if they be ſprung at different times, that the reſiſtance will not be reciprocal, nor the effects of the exploſion ſo great.

160. One of the principal maxims in the defence of a place is, to hold in *readineſs a body of troops to march inſtantly after a mine is ſprung, to take advantage of the enemy's confuſion, and endeavour to regain the covered way, or any other poſt that may have been loſt.* Theſe ſallies ſhould be ſupported by a heavy fire of cannon and muſquetry from every work that bears on the enemy.

A ſecond maxim is, *never to ſpring any of the permanent countermines till every method of retarding the enemy's progreſs, or deſtroying his works above ground has been exhauſted*; for a mine once ſprung is henceforth unſerviceable.

161. Keeping theſe maxims in view, let us ſuppoſe that the chambers under the batteries in breach which have opened, be charged, and the troops ready to ſally: then the mines being ſprung, and their effects aſcertained, the troops advance rapidly to the batteries that have been overturned, throw in a heavy fire, and ſally from the covered way to attack the neareſt lodgments, the moment the enemy appears to be in diſorder. In the mean time, the miners by the means of mantlets placed at the entrance of the countermines, and of tin pipes reaching to the chambers that have been ſprung, endeavour as faſt as poſſible to draw out the foul air and introduce freſh: they then immediately begin to extend the intermediate branches under the glacis, in order to overturn a ſecond time the batteries in breach. If this be impracticable, they muſt employ the remaining chambers to bury the beſieger in making the deſcent into the ditch.

When

When no further advantage can be derived from them, they make in the large gallery a chamber on both ſides of the deſcent into the ditch to deſtroy it.

162. The countermines of the firſt ſtage being ſprung, thoſe of the ſecond remain to overturn the new erected batteries in breach, and deſtroy the deſcent into the ditch; their chambers are charged with the proper quantity of powder for the line of leaſt reſiſtance, taking care to fill up the empty branches or galleries of the countermines of the firſt ſtage that are within reach of the ſhock; otherwiſe the force of the explofion will be ſpent againſt them, without overturning the batteries: when this cannot be done, the charges ſhould be increaſed.

163. The beſieger having at length aſcertained the ſafety of his batteries on the glacis, and in the places of arms, begins to batter in breach; and having completed his deſcent into the ditch, advances under cover of a double epaulment towards the foot of the breach: the beſieged then charge the mines under the different epaulments and breaches with a ſufficient quantity of powder to blow away the rubbiſh that has fallen down from the breach; and make a large excavation in the ditch, that the beſieger may be under the neceſſity of firing a great many more rounds in order to beat down materials to make the breach again acceſſible. The chambers thus charged ſhould be ſet fire to, the moment the enemy mounts in column to the aſſault.

When the countermines under the ditch are ſprung, thoſe in the attacked works ſhould be charged to overturn the lodgments that may be made in them; the charge ſhould be very large in order to throw to a great diſtance the materials, and render the breach again inacceſſible, which will lay the beſieger under the neceſſity of keeping up a heavy fire for ſeveral days, to regain the advantage he has loſt. The moſt favourable moment of ſetting fire to theſe chambers is when the enemy is giving a general aſſault; or when he has brought up cannon through the breach to batter the interior intrenchments thrown up by the garriſon. Springing the countermines in the baſtion will be the laſt effort of the beſieged, unleſs the body of the place be conſtructed on a ſyſtem of demolition, and well countermined; in which caſe, the conduct of the officers will be regulated by the preceding maxims.

CHAP.

## CHAP. VI.

### Of the Defence of Places constructed on a System of Demolition.

164. THE defence of places conſtructed on a ſyſtem of demolition, and countermined, depends on the connection of the works that are to be blown up with thoſe that are to remain entire (Military Architecture, book 3d): as in theſe ſyſtems, a work that is in the event to be demoliſhed, ſhould remain entire unto a certain ſtage of the ſiege, and the mines act only on particular parts, without damaging others; the greateſt attention is requiſite in determining their ſituation and ſize. The four following paragraphs contain the principal caſes that occur, with a few reflections on each.

165. When from the combination of the works, the poſition, number, and ſize of the mines, can with accuracy be aſcertained from an inſpection of the plan of the place, without a neceſſity of performing any previous operation, they ſhould be made before the place is attacked, (Chap. 10, Part 1) and charged a few days before they are to be ſprung.

166. When the poſition and ſize of all the mines are determined, but their conſtruction requires much time and labour, the officer of artillery detached to examine the place previous to the ſiege, ſhould ſpecify the neceſſity and extent of this operation: and, if the ſyſtem be ſo combined, that the mines cannot be made before the ſiege, without weakening the defence of ſome other part, he ſhould point out the ſeveral modes of defence that to him appear moſt feaſible, and give his reaſons in writing; that the commander in chief in laying down the plan for the campaign, may know upon what length of defence he can ſafely reckon.

167. It being impoſſible from the conſtruction of the works to determine the ſituation and ſize of the mines from an inſpection of the plan, the officer of artillery muſt examine how the walls are connected together, in order to aſcertain what parts can be demoliſhed without injuring the others. For the ſake of obviating theſe difficulties, it is to be wiſhed that the mines were always made when the fortifications are conſtructed; and that the walls which are to

be

be blown up were not built into thoſe that are to ſtand, but merely joined to them, or diſpoſed in the manner mentioned in the 3d book of Military Architecture.

168. The ſyſtem of demolition ought to be perfected previous to the inveſtiture of the place: when that has not been done, the artillery officer ſhould ſpecify whether it may interfere materially with the other indiſpenſable operations of the defence: ſince inſtead of being beneficial, it may on the contrary prove very detrimental to the beſieged, by occupying a ſpace of time that can ill be ſpared during the actual defence.

## CHAP. VII.

### DISPOSITIONS FOR DEFENCE OF A PLACE IRREGULARLY BESIEGED.

169. THE ſubject of this chapter applies to all fortifications conſtructed on the modern ſyſtem; to thoſe thrown up on the ſpurt of the occaſion, as well as to thoſe intended to be permanent.

The motives that may induce an enemy to diſpenſe with any of the ſteps uſual in regular ſieges, may be inferred from the ninth chapter, and be reduced to the four following caſes;

1. When in the vicinity there are any favourable poſts that can be uſed to advantage againſt the place.

2. When the fortifications are conſtructed upon a bad ſyſtem, or are out of repair.

3. When the garriſon is weak, and proviſions and ſtores inſufficient.

4. When the garriſon, though ſufficiently numerous, is compoſed of new levies, or of troops whoſe fidelity and courage cannot be depended on.

170. The common axiom, *that if the cauſe be done away the effect ceaſes*, holds good in this as in every other caſe; for by occupying or rendering uſeleſs all poſts favourable to the enemy, repairing the fortifications, and filling the magazines, this kind of ſiege cannot take place. Thus, with a due degree of precaution, it may be wholly avoided in permanent fortifications; yet places fortified through neceſſity, or during a ſtate of hoſtility, may either from defect in ſituation,

tion, or want of time to improve to the utmoſt the natural advantages, be expoſed to it.

171. Suppoſe an officer of artillery detached to a fortreſs labouring under any of the afore-mentioned defects, with orders to make out a plan for the defence: he ſhould attentively weigh every circumſtance that can favour a precipitated and irregular attack, and in his demand of artillery and ſtores, confine himſelf to the neceſſary quantity for oppoſing the beſieger when he arrives at certain given points. Any guns in the neighbouring towns not perfectly good, but competent to the expenditure of the propoſed quantity of ammunition; or any guns of intermediate calibre ſhould be ſent to theſe places, ſince after the ſurrender they will be of no ſervice to the enemy.

172. Again, ſuppoſe a place inveſted by the enemy under circumſtances favourable to a precipitate attack, there are two caſes to be conſidered: the one, with reſpect to places imperfectly fortified and provided only with ſtores, &c. for ſtanding this kind of ſiege (171): the ſecond, with reſpect to regular fortreſſes well ſituated, and abundantly ſupplied with ſtores of all kinds, but of which the garriſon either from ſmallneſs of number, or want of experience or zeal (169, No. 3, 4), is incompetent to a regular defence.

173 In the firſt caſe, the artillery officer guided by the particular motives that influenced the commander in chief to adopt this plan, ſhould exert every poſſible means to protract the ſiege; not keeping up too heavy a fire at the beginning, leſt the ammunition be too ſoon expended: nor on the contrary, permitting the beſieger through remiſſneſs in firing, to lodge himſelf on the works; which will greatly accelerate the capture of the place, eſpecially when they are badly conſtructed or out of repair.

The only method of determining the preciſe line of conduct to be obſerved in this caſe, is to weigh on the ſpot the actual ſtate of the place, with all its advantages and diſadvantages; and from a general view of the whole, to lay down the plan of defence moſt likely to protract the ſurrender.

174. In the ſecond caſe (172), the greateſt efforts ſhould be reſerved, according to the ſtrength of the garriſon, for the body of the place, the ravelin or other out-work, ſo that from the time the beſieger effects a lodgement on the glacis till the place capitulates, the defence will be almoſt regular: when

when there is a ſuperabundance of powder, fireworks, and combuſtibles, large boxes full of powder may be buried at the foot of the breach, the mines on the front of the attack overcharged, large fires lighted on the breaches, and ſupplied with fuel till the whole be expended.

One of the moſt eſſential points towards prolonging the defence in this caſe, is not to expoſe the garriſon to unneceſſarily hard duty. Every avenue by which the enemy can get acceſs to the place through the ditch, as canals, aqueducts, &c. ought to be effectually blocked up, and every precaution taken to guard againſt ſurprize; no more men ſhould mount guard during the night than are abſolutely neceſſary; and even this number ſhould be diminiſhed during the day: the garriſon ought to be well fed, and for the ſake of exciting emulation, any ſoldiers diſtinguiſhed for activity or intrepidity, ſhould be handſomely rewarded. But if the troops, though ſufficiently numerous, be from want of experience or ſuſpicion of their fidelity, unfit to be intruſted with the defence of the covered way; the governor and the principal officers ſhould endeavour to inſtruct them in the moſt ſimple and material parts of their duty, and ſet them examples of indefatigable zeal and exertion: they ought to be particularly careful to prevent their being ſeized with a panic, check all irregularity, and be on their guard againſt mutinies, which frequently happen in regiments compoſed principally of deſerters.

175. The four caſes in which a fortreſs is blockaded, have been already mentioned. To render the blockade of no effect in the firſt caſe (91, No. 1), the magazines and barracks are made bomb-proof, and proper precautions taken to prevent and extinguiſh fire: in large cities expoſed on every ſide to bombardment, where the houſes cannot be ſecured from ſhells and red-hot ſhot, the governor to cover the inhabitants as much as poſſible, ſhould endeavour by the moſt prompt and vigorous meaſures to keep the enemy at a diſtance; by making powerful ſallies, throwing up lines of counter-approach, and ſeizing and fortifying with artillery every ſtrong poſt in the vicinity of the city.

176. When a blockaded city has not the moſt diſtant proſpect of ſuccour, the garriſon ſhould keep up a very heavy fire from their artillery, and frequently make large ſallies, that they may compel the enemy to raiſe the ſiege: by theſe means

means they will at leaſt, expend their ammunition, and not leave a complete arſenal to the conqueror.

In the third caſe, the nature of the defence muſt be determined on the ſpot from the manner in which the enemy carries on and directs his attacks; the greateſt efforts of the garriſon ſhould be oppoſed to the works and batteries that incommode the place moſt, without waſting ammunition againſt the others.

Finally, in the fourth caſe every advantage for which the enemy gives the leaſt opening, ſhould be ſeized; taking care at the ſame time to be ſparing of the ammunition, that there may be ſufficient for maintaining a regular defence, when the beſieger has brought up the neceſſary artillery for puſhing his attacks with vigour.

## CHAP. VIII.

### Of Counter-approaches.

177. COUNTER-approaches are thoſe works which the garriſon throw up either previous to or during a ſiege at different diſtances from the place, to enfilade and take in reverſe the trenches and firſt batteries of the beſieger: hence, by a judicious diſpoſition, he may be ſometimes compelled to convert into a blockade, a ſiege begun with regular approaches, and in the moſt vigorous manner. It ſhould therefore be eſtabliſhed as a maxim, to *make counter-approaches whenever it can be done to advantage.* They may either form a part of a predigeſted plan, or may be adopted on the occaſion from ſome ſudden and unexpected circumſtance that ariſes during the ſiege.

That the nature of counter-approaches may be perfectly underſtood, here follow ſome of the principal caſes in which they can occur.

178. When a fortreſs with a numerous garriſon is only attackable on one or two fronts, and the ground before them is commanded from ſome points within reach of the garriſon, and ſecured from attack, being partly ſurrounded by a navigable river, ravine, precipice, or moraſs; or before which the enemy will be under a neceſſity of opening trenches before he can advance towards the place itſelf, a counter-attack

attack is then projected. The works to be erected in this caſe previous to a ſiege are forts and redoubts, far enough advanced in front of the place to enable them to enfilade and take in reverſe the parallels and firſt batteries of the beſieger: if expoſed to attack, their ramparts are made of the ſame thickneſs as permanent fortifications with good profiles; and covered communications with redoubts at proper diſtances thrown up between them and the fortreſs, to cover them from any attempts of the enemy. They are planted with heavy cannon and mortars, with a proportion of ſtores adequate to their ſtrength and importance.

Sometimes from the nature of the ground, a part of the fortreſs itſelf will ſerve as a counter-approach: in this caſe, the officer of artillery ſhould inſert in his plan of defence the neceſſary number of guns, mortars, and ſtores, for carrying on the counter-approach with vigour, independent of the proportion for the actual defence of the place.

179. When in the vicinity of a place ſituated on a navigable river, or on the ſea-coaſt, into which ſuccours can be occaſionally introduced; there be any points that command the ground where the beſieger muſt open his trenches, they ſhould be ſtrongly fortified, and amply ſupplied with artillery and ſtores; ſince the navigation being open, freſh ſupplies can be at any time thrown in.

180. A fortreſs is ſometimes protected by an intrenched camp, that ſerves to keep the communication open with the country whence it draws its ſupplies; ſtrong works ſhould be thrown up to ſecure any commanding points in the vicinity: the neceſſary quantity of artillery and ſtores for this counter-approach may be aſcertained with ſufficient accuracy, by knowing the extent and nature of the ground where the beſieger muſt open trenches, and erect his batteries; and any additional ſupply may be afterwards introduced under favour of the intrenched camp.

181. It often happens that an enemy in laying down before a fortreſs opens his attack againſt the ſtrongeſt front: in this caſe, if the garriſon be numerous, and the ſituation favourable; that is to ſay, if the ground, on which the works of a counter-approach can be conſtructed, be inattackable, or covered by the fire of the place, they ſhould be inſtantly executed, and planted with the artillery deſigned for the barbette-batteries, and the other parts at a diſtance from the front of the attack. As the introduction of ſuccours is not

ſuppoſed

ſuppoſed practicable, the fire ſhould be directed againſt the batteries that moſt annoy the garriſon; according to the invariable maxim *of protracting the ſurrender as long as poſſible, by employing every thing in the moſt advantageous manner.*

182. An army or a conſiderable corps of troops having been worſted in action, has frequently taken refuge in a large fortified town, where was a depot of heavy artillery; and to which the victorious army has lain ſiege. When this happens, every ſtrong poſt in the vicinity that may ſerve to keep the enemy at a diſtance from the place, and reduce him to the neceſſity of a blockade, ſhould be occupied by ſtrong detachments, and fortified: when the adjacent country is ſo favourable to the conqueror, that he can inſtantly break ground and carry on his approaches in form, the troops in the town ſhould endeavour to form counter-approaches; this being the moſt effectual method of rendering the enemy's enterprizes abortive; or at leaſt of embarraſſing his operations, and lengthening the defence.

Counter-approaches cannot be made in low flat ſituations, except under cover of an impaſſable moraſs or river: in this caſe, a trench 25 feet wide ſhould be made to connect the place and the moraſs or the bank of the river, and the front covered by the body of the place or ſome advanced work: in the rear of the trench may be erected the batteries for enfilading and taking in reverſe the enemy's approaches; and ſome advanced redoubts may, if neceſſary, be thrown up at proper diſtances to ſecure the communications. The works of the counter-approach ſhould be ſo combined with each other and the works of the fortreſs, that the enemy in advancing to attack them, may be taken in front and flank, whatever be the diſpoſition or order of the attack.

It is the province of the engineers to project the counter-approaches; the duty of the artillery officer being only to furniſh them with proper ſtores and defend them: it is unneceſſary therefore to enter farther into the principles of their conſtruction.

# THIRD PART.

## Of the Service of Artillery in the Field.

183. THE two former parts of this work were confined to the ſervice of artillery in the attack and defence of places; but the preſent object being the ſervice of artillery in the field, and nothing having hitherto been advanced on this part of the art of war, it is neceſſary to give a general idea of tactics; in order to explain the principles on which the ſeveral ſpecies of troops operate, and the various combinations that may be made according to the particular exigency.

184. The ſyſtem of a campaign between two armies is called *offenſive*, when one of them ſeeks an opportunity of forcing the other to action; or of obliging him to retire and abandon the country he is maſter of: if both armies ſtudiouſly avoid an engagement, yet ſecretly watch for an opportunity of attacking the adverſary to advantage, this is called *a war between equal forces:* and, an army is ſaid to be on *the defenſive*, when from inferiority of numbers, or ſome other cauſe, the general ſhelters himſelf in ſtrong poſts, covers himſelf with lines and fortifications, or retires till he gains a camp almoſt impregnable; under favour of which he keeps the enemy at bay, or at leaſt, checks for a time the rapidity of his conqueſts.

185. Whatever be the ſyſtem of the war, it always behoves the general to take ſuch ſteps previous to the opening of the campaign, as may inſure, as far as depends on human foreſight, a ſucceſsful iſſue.

The firſt point is to have the army properly *compoſed:* to this end, it is requiſite to have a clear and accurate idea of the peculiar properties and ſervice of each of the three ſpecies of troops, that conſtitute the military force of modern days; viz. infantry, cavalry, and artillery. In the next place, the nature of the country that is to be the theatre of

of war, and the propoſed ſyſtem of operations ſhould be conſidered: ſince the army ought according to the nature of the country to be compoſed either of infantry ſolely; or of infantry and artillery; or of infantry, cavalry, and artillery. The proportion of each ſpecies of troops varies alſo, accordingly as the country is level or mountainous; interſected by rivers, ravines, and moraſſes; or covered with woods: the number and quality of the enemy's troops is likewiſe another point eſſential to be aſcertained.

## CHAP. I.

### OF THE SEVERAL SPECIES OF TROOPS THAT COMPOSE AN ARMY.

186. UNIVERSAL experience proves that the ſucceſs of an army depends on its compoſition, and the manner in which its marches and diſpoſitions in the day of action are regulated.

There are certain judicious combinations founded, in the opinion of the beſt military writers, on the different ſervices of the ſeveral ſpecies of troops, and on the manner in which each can act; relatively to the nature of the country and the method in which the ſoldier is armed.

187. The muſquet with the bayonet is an arm which the foot-ſoldier carries with eaſe: with it he can march through narrow paths, and over mountainous and difficult roads; and a bridge of ſlight conſtruction ſerves for his paſſage over rivers, canals, or broad ditches.

In common marches that continue about 6 hours, a ſoldier walks with a free and natural ſtep 2 $\frac{1}{3}$ miles in an hour; a regiment therefore when the roads are tolerably good, marches 14 miles in 6 hours. Within reach of the enemy, the pace is regular, but quicker or ſlower, according to circumſtances: in the ſlow movement, calculating each ſtep at 24 inches, and 60 ſteps in a minute, a regiment of infantry paſſes over 40 yards in a minute: and when it moves with an accelerated pace, it paſſes over twice this ſpace or 80 yards in a minute.

188. From the conſtitution of infantry, the ſmall ſpace that each ſoldier takes up, and the arm he carries, this ſpe-

cies of troops is well adapted to offenſive or defenſive operations in all kinds of countries: ſince they can fight in line or column; halting or marching; firing with ball when at a diſtance from, or charging with bayonet when cloſe to the enemy.

The intention of fire-arms being to annoy the enemy at a diſtance, the foot-ſoldier ſhould above all things be taught to load his muſquet properly; and level and direct it well againſt the object: platoon firing by word of command from the officers is never ſo deſtructive as when each ſoldier takes his object ſeparately: this is called *palliſadoe firing*, when the muſquet reſts upon any thing.

Infantry having occaſion for very few carriages, are eaſily ſubſiſted in countries where forage is ſcarce.

189. Cavalry are highly uſeful in marches and engagements, when the country is ſufficiently level and open, to give them room to perform their ſeveral evolutions. The rate of marching of a regiment of cavalry for 6 hours is calculated at 17 miles; but in caſe of neceſſity, it may be extended to 21 or even 28 miles. Wherefore from the celerity of their movements, they are excellent for making incurſions into an enemy's country; ſupporting a diſtant poſt, or corps of troops; cutting off detachments, convoys, or foraging parties that imagine themſelves in ſecurity; and purſuing an enemy when routed and retiring in diſorder. The ſabre, carabine, and piſtol, are the arms carried by the cavalry. In action their great advantage conſiſts in the celerity of their movements, and the impetuoſity of their charge, ſword in hand. The velocity of the latter is eſtimated at four times the velocity of infantry, or from 3 to 400 yards in a minute; but this exertion can laſt but a very few minutes. When an army is drawn up in order of battle, the cavalry is poſted on the flanks to cover the infantry, and be ready to charge the flank of the enemy's army.

The fire of cavalry, from its great uncertainty, and the difficulty of re-loading on horſeback, is but little conſidered in action; it is ſerviceable on guard, in protecting their quarters, ſkirmiſhing, and increaſing the diſorder and confuſion among the enemy's cavalry, when broken by a charge. The country, in which a large body of cavalry is to be ſubſiſted for a long time, muſt abound in forage.

190. Dragoons are a ſpecies of troops that act occaſionally as infantry or cavalry: in open and level countries they perform

perform the duty of cavalry, and in ſtrong and incloſed countries, diſmount and act as infantry: wherefore inſtead of a carabine, the dragoon is furniſhed with a muſquet.

191. On conſidering the peculiar properties of infantry and cavalry, it is evident that whenever theſe two ſpecies of troops engage each other, the ſafeſt method for the infantry is to act on the defenſive, endeavouring to prevent the cavalry from ſurrounding them and charging their rear: they ſhould therefore take poſſeſſion of ſome ſituation that is naturally ſtrong, or may be eaſily made ſo. But if nothing like a breaſt-work can be found, they ſhould form in the beſt manner for keeping the enemy at a diſtance by a briſk fire, in order to enable them to execute the manœuvres beſt calculated for ſecuring their retreat. In ſhort, the diſpoſitions of infantry conſiſt in their order of march, and in regulations for keeping up a heavy fire in time of action.

Cavalry will have a great advantage over infantry when the latter are poſted on a plain, and expoſed to be charged the inſtant they have given their fire, or begin to be in movement; or when they are drawn up in ſuch a manner, that they cannot well ſuſtain the ſhock of a charge, as three deep.

192. Under the name of field-artillery are comprehended the royal regiment of artillery, the guns with their ammunition, horſes for drawing them, and drivers for taking care of the horſes. Hence, from the number of carriages, artillery cannot ſubſiſt long in a country where forage is ſcarce. The roads for artillery ought to be wide and good, and the bridges ſtronger than either for infantry or cavalry; then, the common rate of marching artillery is from 14 to 17 miles a day, and with the ſame expedition as infantry.

When guns are poſted in the front line of an army that is advancing to the attack, the ground ſhould be level and open, that they may preſerve the poſts aſſigned to them in the intervals of the troops: in incloſed countries, they ſhould be preceded by a number of pioneers and carpenters for filling up ditches, making bridges, cutting down hedges, and opening roads: yet ſometimes in ſpite of every exertion, they cannot reach their deſtination, and are frequently much embarraſſed to keep their proper ſtations. Hence it reſults, *that artillery cannot always take the ſame route as infantry, nor accompany them on every expedition.*

When the army halts with an intention of giving battle,

or remains in a fixed poſt, the guns are drawn up at the diſtance of 8 or 10 paces from each other.

193. To leſſen the difficulties that ariſe from the badneſs of the roads or the unevenneſs of the country in offenſive operations, the guns ſhould be made lighter; but not in ſuch a degree, as render their effects uncertain. The 8 and 4 prs. deſcribed in the preceding treatiſe charged with $\frac{1}{8}$ of the weight of the ſhot are more manageable than thoſe of the common length; and are ſufficiently reinforced to reſiſt the exploſion, and project the ſhot with the requiſite force for killing men and horſes. In a word, pieces of this kind will be fully adequate to every purpoſe of firing round or caſe-ſhot; if regard be paid to the diſtance and diſpoſitions of the enemy.

194. A round ſhot, fired againſt a body of troops drawn up in order for battle, can deſtroy but one file of three or four men, whatever be its diameter or velocity. But, if fired ſo as to enfilade the ſame body of men, or againſt a column, it will do execution till its force be entirely ſpent: its effects are then in proportion to its diameter and velocity. For it was proved in the Treatiſe on Projectiles, that the effects of ſhot are in a ratio compounded of their diameter and the ſquare of the velocity with which they impinge: and in the preceding treatiſe, it was demonſtrated that the initial velocities of 8 and 4 lb. ſhot being equal, their effects when fired againſt a body of men near to them, are in the ratio of their diameters, or as 5 : 4; but in long ranges, the reſiſtance of the air being greater to ſhot of ſmall than to thoſe of larger diameter (Treatiſe on Powder); the remaining velocity of a 4 pr. will be leſs than that of an 8 pr. and its effects as 1 : 4. Each man may be ſtruck in front or flank, in the moſt ſolid or leaſt reſiſting parts of the body; it is impoſſible therefore to aſcertain the exact number of men, that one ſhot will kill or maim: the only point that can be aſcertained is, that a 4 lb. ſhot diſcharged from a light 4 pr. with 1¼ lb. of powder and well wadded, ſtriking a column of infantry in the leaſt advantageous circumſtances cannot deſtroy more than 30 men; but under the moſt advantageous circumſtances may kill or wound more than 60.

195. In action, caſe-ſhot is fired from 8 and 4 prs. when the enemy is at a diſtance of about 170 yards, and drawn up with ſuch an extended front that it will do more execution than round ſhot. The number of men diſabled by one caſe-

caſe-ſhot compoſed of 60 ſmall balls projected from a 4 pr. within proper diſtance againſt an extended front, will far exceed what will be killed or wounded by a round ſhot of the ſame diameter.

196. Quick firing is of very eſſential ſervice, either when the enemy's diſpoſition can be enfiladed by round ſhot or expoſed in front to caſe-ſhot: for the ſake of expedition in loading, the powder is incloſed in flannel cartridges; which prevents the accidents that might otherwiſe happen, as the flannel leaves nothing burning in the gun.

In general, at the beginning of an engagement the enemy's army is at a great diſtance, and preſents but a ſmall front; in this ſituation, from the great care requiſite in loading and laying the guns, ſome minutes elapſe between every two rounds. If the enemy's front be very extended or he is advancing, the guns need not be laid with ſo much accuracy, and the wads may be diſpenſed with; which will tend to accelerate the firing. At length when the armies are very near each other, it is no longer neceſſary to lay the gun each time, the caſe-ſhot is fixed to flannel cartridges, the uſual method of ramming the charge is diſcontinued, and the guns are primed with tin tubes: the artillery in this caſe fire faſter than the infantry can do, and the gun is loaded in three motions.

1. The caſe-ſhot fixed to a flannel cartridge is put into the gun.

2. It is puſhed to the bottom of the cylinder with one ſtroke of the rammer.

3. The rammer is drawn out, and at the ſame inſtant the tin tube is introduced into the vent. The gun, when heated, may be cooled with a wet ſponge.

197. Different ſyſtems of artillery have been from time to time deviſed with a view of firing quicker in action: from an impartial compariſon of theſe ſeveral ſyſtems with the 4 and 8 prs. in queſtion, it might be aſcertained how far the adoption of any of them would be really advantageous.

198. The diſtances at which artillery and infantry may engage, may be reduced to three; and the advantage of each arm is relative to the diſtance.

1. The diſtance may exceed the range of a muſquet; or

2. It may be from 200 to 260 yards,

3. It may be leſs than 170 yards.

In the firſt caſe, it is clear that the whole advantage lies on the ſide of the artillery; more eſpecially when the enemy can be taken in flank.

199. But in the ſecond caſe, the ſuperiority reſts with the infantry when drawn up three or four deep; ſince each gun is expoſed to the fire of ten files, or 30 or 40 muſquets, which may make great havock among the artillery-men; while the utmoſt execution that a gun can do, is to carry off one file at each diſcharge: the fire of the infantry may be alſo better directed, and quicker than that of the artillery from the neceſſity of laying the gun every time to enſure execution: moreover, the infantry always continue firing in proportion to the number of men that remain, whatever loſs they may have ſuſtained; whereas the fire of artillery decreaſes in a much greater ratio: thus, if half of the gunners be diſabled, the fire diminiſhes in a quadruple or even greater proportion. Hence if a body of infantry be drawn up 4 deep at 200 or 240 yards from a field-battery, or be poſted behind fences or walls, whence they can keep up the palliſadoe firing, the artillery will be more galled and ſooner diſabled than by oppoſing gun to gun. The idea which the greater part of military men have without due reflection adopted, of the vaſt ſuperiority of artillery has not a little contributed to increaſe its effects; even veteran troops have under the influence of this terror been incapable of improving the advantages they had obtained; and new levies have been known ſhamefully to turn their backs at the very report of the guns and whiſtling of the ſhot: for when ſhot are not perfectly ſpherical or are full of cavities they make a hiſſing noiſe in the air, that ſtrikes a panic into raw or unſteady troops; and the horſes and drivers can with great difficulty be prevented from running away.

200. In the third caſe (198) the artillery has evidently the advantage; for they can fire faſter than the infantry, and each gun projects at every diſcharge a greater number of balls than the ten files oppoſed to it (196).

When the infantry unable to bear any longer the galling of the caſe-ſhot, ceaſe firing, and advance to the charge; the artillery ſhould profit of their error and fire as faſt as poſſible, putting over the caſe two or three round ſhot if the enemy be drawn up very deep. In doing this there is no reaſon to be afraid of burſting the guns conſtructed on the principles laid down in the preceding treatiſe.

To

To give an idea of the advantage that the artillery has in this caſe; let us ſuppoſe the enemy to advance in quick time or at the rate of 80 yds. in a minute; the guns will eaſily (196) make three diſcharges in a minute without being annoyed by the enemy, whoſe firing has ceaſed; ſo that while the infantry is marching the diſtance of 170 yds. to attack the cannon, they will be expoſed to ſix rounds of caſe-ſhot from each gun, which will be more deſtructive the nearer they approach.

201. Artillery when oppoſed to cavalry, and covered in front by a broad and deep ditch, and ſecured in the rear by chevaux-de-frize, &c. has greatly the advantage; but when from the nature of the ground they are entirely expoſed, the flanks and rear ſhould be covered by detachments of infantry or in ſome other manner. Each gun ſhould be fired twice in half a minute, being the time that cavalry takes to gallop at full ſpeed over a ſpace of 170 yards, which is the greateſt velocity that cavalry can charge with.

Guns of the largeſt calibre ſhould be oppoſed to cavalry, as they project a greater number of ſmall balls, and with round ſhot do more execution in enfilading (194).

202. Theſe ſeveral ſpecies of troops compoſe the bulk of armies; and from their ſolidity and mutual ſupport when properly combined together, are deſtined for all great military operations.

There are other troops, which differ much from the former in their ſervice and method of fighting: they are diſtinguiſhed into light-infantry and light-cavalry, and are deſigned to act by detachment; for ſecuring the tranquility of the camp; covering convoys; beating up the enemy's quarters; and harraſſing them on marches. On them devolve all the more minute duties; but as they are never accompanied by artillery, it is needleſs to examine their conſtitution more particularly. The neceſſity of being acquainted with the method in which the ſeveral ſpecies of troops that compoſe armies can act, and be combined together on marches and in action, according to the nature of the ground and the diſpoſition of the enemy, will from the peruſal of this chapter be obvious to every officer.

CHAP.

## CHAP. II.

### Reflections on the Composition of an Army.

203. TO compoſe an army judiciouſly, the nature of the country, the quality of the troops, the number of the enemy's forces, and the plan of the campaign muſt be previouſly conſidered. A general, maſter of theſe points, may make the moſt advantageous and maſterly arrangements: whereas, an army formed without attention to this general maxim, will labour under manifold diſadvantages; and probably in the event reap nothing but diſgrace and defeat, or, at moſt, but partial ſucceſs.

204. The firſt requiſite in the formation of an army is, that *it be quick and rapid in its movements, and ſubſiſted without difficulty:* wherefore *it ſhould be limited in number, reſtricted in quantity of baggage,* and *free from every unneceſſary incumbrance.* The movements of very large armies are ſo ſlow and their marches ſo ſhort, that their number by no means compenſates for the heavy additional expence: beſide, from the difficulty of providing ſuch numerous bodies of troops with forage and proviſions, a general is frequently obliged to abandon entire provinces, and to move into an open country within reach of ſome navigable river, by which the means of ſubſiſtance may be facilitated. When the theatre of the war is in a very ſtrong country, a ſkilful general will turn this circumſtance to advantage, and regulate the number of his troops accordingly. We find in hiſtory numberleſs examples of celebrated captains, who with ſmall armies have by a judicious choice of poſts and encampments, made head againſt an enemy greatly ſuperior in number; and in the event, by a ſeries of rapid and maſterly manœuvres reduced him to the greateſt ſtraits.

By conſtant habits of ſurveying ground in a military point of view, and ſuppoſing the various caſes that may occur on ſervice, officers may acquire a quickneſs in diſcerning the advantages and diſadvantages of poſts; which has ever been eſteemed among the firſt qualities of an able general.

205. After determining the number of troops of which the army is to conſiſt, the next point is to aſcertain the proportion

portion of each ſpecies of troops; taking care to diſtinguiſh thoſe deſtined for the grand operations of war, from thoſe that are to carry on the *petite guerre*: for if the light troops be too few in number, the ſtrength of the army inſtead of being preſerved entirely for great occaſions, will be exhauſted by the daily fatigues they muſt undergo: on the contrary, too numerous a corps of light troops militates againſt the maxim laid down in the laſt paragraph.

206. When the theatre of war lies in a very mountainous country, the army ſhould conſiſt ſolely of infantry; to whom may be attached ſome 4 prs. to be placed in fortified poſts, when ſuch points of ſupport are neceſſary in a defenſive ſyſtem. But no artillery ſhould accompany an army that is to act offenſively in a mountainous country, unleſs it be to occupy an intrenched poſt in order to cover the operations of the troops; to attack a ſtrong intrenchment to which it is practicable to bring up cannon; or take advantage of ſome commanding eminences to diſlodge the enemy.

207. In flat countries interſected by rivers, canals, ditches, hedges, defiles, &c. the army ſhould be compoſed of infantry, dragoons and artillery; the train of artillery conſiſting of a few 4 prs.

In open champaign countries, the train of artillery may be more numerous and conſiſt of pieces of larger calibre: the principal ſtrength of this army ſhould lie in its cavalry; ſince by their means the general will be maſter of the country and oblige the enemy to keep cloſe to his camp, or cover his convoys and foragers with large detachments; which will greatly harraſs and weaken his army.

208. The proportion between the infantry and cavalry depends alſo on the nature of the country. In flat extenſive countries, the cavalry including the light-cavalry may be eſtimated at $\frac{1}{4}$ of the whole army; this number diminiſhes ſucceſſively to $\frac{1}{6}$, $\frac{1}{8}$, $\frac{1}{10}$ in proportion as the country becomes ſtronger; till at length cavalry is totally excluded and their place ſupplied by dragoons; who may amount to $\frac{1}{5}$ or $\frac{1}{20}$ of the army, when the country though level is very ſtrong (207).

209. The number and quality of the troops being thus determined, they are formed into what is called *an order of battle*. The firſt line conſiſts of at leaſt half of the battalions

lions and ſquadrons: the remainder are diſpoſed in the ſecond line; and there is frequently a corps de reſerve or third line, but leſs numerous than either of the others. Each line is ſubdivided into brigades; the brigades of infantry conſiſting of 5 or 6 battalions, and thoſe of cavalry of 8 or 12 ſquadrons: each brigade is commanded by a major general and a brigadier; and every two or three brigades are under the orders of a lieutenant general. The light troops form a ſeparate corps under the command of a general or field officer, whoſe rank is in proportion to the ſtrength of the corps. The chief command of the army is given to a captain general; who has under him a general of cavalry, when that body is numerous.

## CHAP. III.

### Of the Field Train of Artillery.

210. THE number and calibre of guns for compoſing a train of artillery to accompany an army in the field, is determined by the nature of the country, the ſyſtem of operations, and the number of the troops; in order that the artillery may augment the reſources and ſupport the diſpoſitions of the commander in chief, without cauſing the leaſt delay or embarraſſment.

211. When the ſcene of operations lies in an open champaign country, the train of artillery is the largeſt (206): it has for a ſeries of years been cuſtomary to reckon one gun for every thouſand men; theſe pieces are worked by the royal regiment of artillery.

But during the war that commenced in GERMANY in 1740, field-pieces were attached to each regiment of infantry: they were ſerved by them and comprized in the ſtores of the regiment. As ſeveral other nations have adopted this maxim, it will be for our intereſt to add to the ſtrength of our infantry by purſuing the ſame plan, if ever we have occaſion to act againſt any of them in a champaign country; notwithſtanding the expence and trouble that ſuch a quantity of artillery muſt occaſion.

In flat but very ſtrong countries, where the object is not to bring on a general action, but by marching and manœuvreing

vreing to occupy advantageous poſts; the principal point to be conſidered is celerity of movement (204): wherefore, the army ſhould be diſincumbered of the battalion guns, the train of artillery diminiſhed, and the nature of the guns adapted to the uſe for which they are principally deſigned, and to the condition of the roads and bridges; that they may never retard the march of the troops: in hilly countries, their number ſhould be farther dimiſhed.

In mountainous countries, the uſe of artillery ſhould be entirely ſuppreſſed, unleſs ſome poſt of importance is to be occupied. From a deſire of carrying cannon with troops that are to act among mountains, ſmall guns weighing from 1 to 2 cwt. have been invented, and are tranſported on the backs of mules; but the advantages reaped from them are inadequate to the expence and trouble attending them.

212. For the ſake of laying down ſome rule for forming field trains; let us ſuppoſe an army of forty battalions and as many ſquadrons, making in the whole 30,000 men, acting in a flat open country, with an intention of ſeizing every favourable opportunity of coming to action. In this caſe, beſide the 4 pr. battalion guns ſerved by the infantry, there ought to be twenty-five 8 prs. weighing from 9 to 10 cwt. each; four 16 prs. weighing from 17 to 18 cwt.; and four howitzers; with a proportion of ammunition, from 90 to 120 rounds a gun (one third of which ſhould be caſe-ſhot); carried in tumbrils; with a certain number of waggons for the muſquet cartridges and flints; to this muſt be added a proportion of intrenching, black-ſmiths and carpenters tools. That the ſervice may be carried on with regularity and diſpatch, draught horſes ſhould be purchaſed, drivers inliſted (1) and formed into a corps under officers and non-commiſſioned officers: the number of horſes is regulated by the quantity of ammunition, &c. never allowing more than $5\frac{1}{2}$ cwt. to each pair of horſes beſide the weight of the carriage; that they may not be worn out before the end of the champaign. The guns are diſtributed into brigades of 5 or 6 pieces each, to be employed together or ſeparately, as occaſion may require, with a detachment of artillery-men to ſerve them.

Let the twenty-five 8 prs. be divided into five brigades; the howitzers and 16 prs. will form the ſixth or park brigade; which is reſerved for cannonading works that cover brigades, and ſtrong poſts of all kinds; and for firing againſt cavalry,

cavalry, or oppoſing very powerful attacks of infantry: the particular deſtination depends on the ground and diſpoſitions of the enemy.

213. The following is a return of horſes, &c. for one brigade of 8 prs.

| | *Horſes.* |
|---|---|
| Five 8 prs. mounted on travelling carriages, with limbers, ſide-arms, coins, and hand-ſpikes, with 4 horſes to each | 20 |
| Two ſpare carriages, with limbers, carrying 4 ſpare wheels, 4 ſpare axle-trees, 4 ſets of ſide-arms | 4 |
| Seven tumbrils carrying 500 rounds for the above guns | 14 |
| One light waggon with intrenching tools, &c. for repairing roads and bridges | 4 |
| One travelling forge complete | 2 |
| One waggon carrying 4½ cwt. of iron-work for gun carriages, 2 cwt. of ſpare rope, 1 cwt. of greaſe, carpenters tools, lanterns and 1 cwt. of candles | 4 |
| Six powder waggons carrying 60000 muſquet cartridges, 30000 flints for muſquets, 2000 flints for piſtols, 3½ cwt. of powder, 5½ cwt. of muſquet and piſtol ball, and 10 reams of cartridge paper | 24 |
| Two waggons carrying oats for the horſes with ſpare harneſs | 8 |
| Horſes for one officer, two non-commiſſioned officers and a farrier | 4 |
| Number of horſes for one brigade | 84 |

Beſide the above, two country carts drawn by two pairs of oxen for carrying more intrenching tools, and the officers baggage belonging to the brigade.

When the brigade conſiſts of 4 prs. two horſes are allotted for each gun, and four tumbrils for the ammunition; the reſt as above. Should the army move to a diſtance from the arſenals or fortified towns, a large depôt of ammunition both for infantry and artillery ought to be brought forward and lodged in ſome caſtle or walled town under the care of a detachment of infantry.

214. The

214. The detachment of artillery for the ſervice of each brigade conſiſts of a captain and two or three ſubalterns; ſix or eight non-commiſſioned officers; ten or twelve artificers; with eight or ten gunners to each gun, according to its calibre, and a conductor of ſtores for taking care of the ammunition, &c. All the brigades are commanded by a field officer, who has under him an adjutant and two aſſiſtants. The commiſſary general of artillery detaches a commiſſary, to make the iſſues and purchaſes during the campaign.

215. When a broad river runs through the country in which the army is to act, a ſufficient number of large boats are provided for making bridges, and are left in the water till wanted.

When there are ſeveral ſmaller rivers, a number of pontoons accompany the army, carried on proper carriages, with baulks, cheſſes, cordage and every thing requiſite for conſtructing bridges: an officer of the artificer-company with a party of artificers has the charge of this duty. The number of pontoons is regulated by the bridges there may be a neceſſity of making, and by the breadth of the rivers: the common calculation is a pontoon for every 16 feet of breadth, beſide the two for the centre; if the river be navigable. The conſtruction of theſe bridges has been already mentioned (37).

216. The following is a proportion of pontoons, &c. for laying a bridge over a river 300 feet broad.

| | *Pairs of Oxen.* |
|---|---|
| Twenty pontoons mounted on carriages ..... | 60 |
| Twenty-four carts carrying 360 cheſſes or planks 13 feet long, from 10 to 14 inches broad, and 2 inches thick ..... | 24 |
| Fifteen ditto, carrying 120 baulks from 16 to 18 feet long, and from 4 to 7 inches thick ..... | 15 |
| Eight ditto, 10 anchors and cables, ſheer-lines, 6 capſtans, artificers tools ..... | 8 |
| Number of pairs of oxen | 107 |

Inſtead of pontoons, boats made of leather are ſometimes carried in waggons folded up; when wanted for uſe, they are ſtretched out with croſs pieces of wood, and 4 axle-trees fixed

fixed to the bottom furniſhed with ſmall wheels, that they may run into the water without being damaged; upon them is laid a kind of ſtage, and over that the bridge is conſtructed.

In mountainous countries, ſmall leather boats are carried on the backs of mules; each mule carries two. Bridges made of theſe boats will not ſupport a weight exceeding 10 cwt.

In laying bridges of all kinds, whenever the river is ſo ſhallow that a heavy weight would ſink the boat till it touch the bottom of the river, treſtles ſhould be ſubſtituted in their room, for reaſons too obvious to need mentioning.

## CHAP. IV.

### Of the Encampment of an Army, and of the Park of Artillery.

217. THE troops that are to compoſe an army are drawn out of their cantonments and quarters at the beginning of the war or of each campaign, and march to ſome particular place where they encamp in order of battle (209). As the place of rendezvous is always at a diſtance from the enemy, it is ſufficient if it be dry and abounding with wood, water, hay, and ſtraw: but the other camps that the army may occupy in the courſe of the campaign, independent of theſe requiſites, muſt in other reſpects correſpond with the views of the general: the firſt object is the ſecurity of the troops; wherefore,

1. There ſhould be in the front of the encampment a ſpot ſpacious enough to draw up the whole army in two lines, and to engage without being embarraſſed by the tents.

2. The front and flanks ſhould be covered by houſes, villages, rivulets, ditches, ponds or ravines, which the enemy cannot paſs in order of battle.

3. Above all, the rear of the encampment ſhould be ſecured, and a free communication eſtabliſhed between the magazines.

4. Any villages, houſes, or high-grounds near the camp, ſhould be occupied by ſtrong detachments.

5. If

5. If the camp be interſected by canals, ditches, rivulets, or other obſtacles to a free communication between every part of it, bridges ſhould be laid and paſſages opened, that the whole may eaſily move to the ſupport of any part that is attacked.

218. In nothing is the ability of a general more conſpicuous than in the choice of his encampments; and few circumſtances have conduced more than this to gaining the moſt brilliant victories; but as the full diſcuſſion of this intereſting part of tactics would be foreign to the purpoſe, our obſervations will be confined to a few points.

(Fig. 10, Pl. 6) The ſixth plate repreſents a common encampment of 40 battalions and 40 ſquadrons; A, the encampment of the firſt line; B, that of the ſecond, diſtant from the firſt 6 or 800 paces; C, brigades of infantry of five battalions each; D, brigades of cavalry and dragoons of 10 ſquadrons each; E, the park of artillery; F, head quarters; G, the village whence the camp takes its name; H, ground for the firſt line to draw up in order of battle, diſtant from A at leaſt 600 paces; I, ground for the ſecond line to draw up in order of battle; K, houſes or barns occupied by the advanced guards of infantry; L, advanced guards of cavalry, as poſted during the day; M, points to which the cavalry retires during the night to be covered by the infantry.

As many paces are allowed for the front of each battallion as it contains files; and an interval of at leaſt 20 paces is left between every two battalions of the firſt line, that thoſe of the ſecond line may, if neceſſary, paſs through them and form at I.

As many paces as there are files in each ſquadron and one half more are allowed for the front of each ſquadron; with an interval between every two of at leaſt half the front of a ſquadron, that thoſe of the ſecond line may paſs without interruption, and form at I. This diſpoſition is nearly regular when the ground is level and open; but is deviated from, if ſuperior advantages can be gained by a different poſition, or the ſafety of the camp better ſecured. When one flank is covered by a ravine, river, lake or impaſſable moraſs; and there is on the other a flat open piece of ground, all the cavalry is encamped on this flank.

219. This mode of encampment has been generally practiſed for theſe two laſt centuries; but in the defenſive ſyſtem,

other modes are adopted, ſuch as the *cloſe* and the *extended* camp. In the cloſe camp, the army is encamped in three or four lines; and with the antients, its form was ſquare or rectangular, with little difference between the length of the ſides in open and level ground; but the moderns without regard to the figure, attend only to the nature of the ground, endeavouring effectually to ſecure ſome of the ſides, that they may be the better able to oppoſe the enemy at the vulnerable points. Such poſitions are frequent in mountainous countries; and thoſe are eſteemed the ſtrongeſt, that are on a ridge between two vallies or rivers, or on a riſing ground with a river in the rear; ſo that the enemy however numerous, cannot ſurround the camp or cut off the ſupplies. In the extended camp, the whole army is encamped in one line; when from ſituation or circumſtances they are under no apprehenſion of being attacked, and wiſh to prevent an enemy from paſſing a broad river, or occupy a chain of poſts in the mountains to cover a country.

220. The brigades of artillery being prepared, and the captain commanding each having inſpected it, and received his order of march; they are put in motion along the high roads, and join the army in one or more days journey, according to the diſtance: when their route lies through a ſuſpected country, they are eſcorted by a competent number of infantry or cavalry, as the country is more or leſs level or mountainous.

The commanding officer ſends forward the quarter-maſter and camp-colour-men early in the morning to the village where he intends to halt, in order to prepare quarters and forage, and mark out a piece of ground for the park. When the brigades reach the army they are drawn up in four lines on the ground pointed out by the commander in chief, with 6 or 8 paces between every two carriages, and 20 paces between every two lines; that the horſes may be harneſſed and the march reſumed without confuſion: the guns, light-waggons, and ſpare-carriages in the firſt line; the tumbrils in the ſecond; the ammunition-waggons in the third; and the waggons with the intrenching tools and the forge cart in the fourth: the brigades are called after the captains that command them, and are drawn up according to ſeniority; the firſt brigade on the right, the ſecond on the left of the firſt, and ſo on ſucceſſively to the laſt, which is generally the park brigade.

In

In front of the park and about the centre, a quarter-guard is placed ſufficiently numerous to furniſh centinels; and two alarm guns are ſtationed there, and kept unlimbered with a lighted match to give ſignals for the army to get under arms. The non-commiſſioned officers and ſoldiers tents are pitched on each flank of the park. at the diſtance of 20 paces from it; and 40 paces in the rear are pitched the officers marques in two lines. At ſome diſtance in the rear of the marquees, the horſes are picketed in two or more lines with the tents of the drivers, &c. on the flanks.

221. The brigades being arrived, the commanding officer makes his report to the commander in chief, and waits on him every day for orders; and the adjutant goes every day at orderly time to take the detail of duty. When the camp is pitched the artificers examine the carriages, and the conductors of horſe inſpect the harneſs; at the ſame time the conductors of ſtores examine the tumbrils and ammunition waggons of their reſpective brigades, to ſee if any thing has been damaged or diſplaced during the march. The officer on guard over the park ſhould go his rounds two or three times during the night, and cauſe them to be repeated by the ſerjeant and corporal of the guard: he ſhould alſo take care that the cooking places are at a diſtance from the park, and all fires extinguiſhed at ſun-ſet, and even during the day if the wind blow hard. The next morning before the guard is relieved, each conductor goes round his brigade attended by a non-commiſſioned officer of the guard, to ſee that nothing has been ſtolen or broken during the night.

222. When the park of artillery is placed between the firſt and ſecond line, it is ſuppoſed that there is no danger of being attacked: (Fig. 10, Pl. 6) but when the vicinity of the enemy's army renders precaution neceſſary, the brigades of artillery are poſted between the brigades of the firſt line of infantry, and on the flanks between the infantry and cavalry. Each brigade is then ſubdivided: one part conſiſts of the guns, light waggons, ſpare carriages, and tumbrils, with the officers and greater part of the gunners; the carriages are drawn up in two lines in the intervals of the firſt line of infantry, with the mens tents on the flanks, the officers marquees in the rear, and the horſes and drivers behind them: when 100 paces are allowed for the front of each brigade, this diſpoſition is called *the artillery drawn*

*up in order of battle.* The other part which includes the remainder of the brigade under the care of a non-commiſſioned officer with ſome gunners and the conductor, are ſtationed between the two lines of the army, or in the intervals of the ſecond line: thoſe ſubdiviſions are frequently drawn up together, and go under the general name of the depôt; and then an officer is ſent to command them.

When the ground in front of the field of battle is low, and there are any points that command the roads by which the enemy muſt advance to the attack, ſome guns ſhould be poſted there ſupported by pickets of grenadiers, or other choſen troops encamped on their flanks.

## CHAP. V.

### OF THE MARCH OF AN ARMY, AND OF THE DISPOSITION OF THE TRAIN OF ARTILLERY.

223. LONG and frequent marches fatigue troops and occaſion ſickneſs; wherefore no march ſhould be made, unleſs ſome real and eſſential object is propoſed from it. Previous to a movement, a general takes into one point of view the plan of operations; the nature of the country the army is to paſs over; the time requiſite for performing the march; the enemy's force and diſtance: and thence determines in how many columns the army ought to be diſpoſed, that the march may be eaſy and expeditious, and the troops ſoon formed in order of battle, in caſe of an attack on the march; how each column ſhould be compoſed, and which road it ſhould take.

When there are not roads enough for the ſeveral columns, the cavalry croſs the fields, and the infantry march on the roads; the columns of artilery on the broadeſt and beſt. The light troops are ſent forward early in the morning to reconnoitre the country; and if the enemy be near, they are ſupported by a conſiderable body of troops: in their rear march the detachment intended to guard the new encampment, with the camp-colour-men that are to mark it out. But if the enemy be at a diſtance, the camp-colour-men aſſemble at a certain time and place, and proceed with the camp-guard, and the quarter-maſter-general under the orders

orders of the general of the day, towards the new encampment. On their arrival, the quarter-maſter-general marks out the camp, and the general of the day poſts the neceſſary guards.

Each column has a front and rear guard; the ſtrength of the detachment that covers the artillery and baggage is determined by circumſtances.

224. When the drummers *beat the general*, the quarter-maſter and camp-colour-men of the artillery repair to the place appoined for their aſſembly, and accompany the other camp-colour-men to the new camp; and every thing is prepared for the march.

At the beating *of the general*, the artillery-men ſtrike their tents, pack their baggage, and harneſs and bridle the horſes: at the ſecond ſignal, or *the aſſembly*, the horſes are put to the carriages, and they are all drawn up ready to march; and at the third ſignal, the whole move into the place aſſigned to them in the order of march. The brigades march according to the ſeniority of their captains, with the light waggons in front; then the guns, the tumbrils, the ammunition waggons, waggons with intrenching tools, and laſt of all the country waggons and forge carts. Each captain with the greater part of the gunners marches at the head of his brigade; a ſubaltern with a ſmall detachment in the rear; and another detachment under a non-commiſſioned officer on the flanks near the ammunition, which is alſo the ſtation of the conductor of ſtores. The artillery column is preceded by ſome pioneers taken by detachment from the ſeveral brigades; and ſome artificers to mend holes in the roads, examine the bridges, repair them or lay down new ones, and open avenues into the park, in caſe the camp-colour-men have not had time to do it. When the brigades reach the new encampment, they are drawn up as before.

225. The ſeventh plate repreſents an army on its march in five columns from the encampment A towards B: (Fig. 11, Pl. 7) the centre column of artillery C is preceded by a brigade of infantry D, and followed by a part of the baggage of the army: the remainder of the baggage F forms the fourth column with two brigades of infantry in front; H, the van-guards of each column; I, the rear-guards; K, the new encampment and the camp-colour-men; L, light troops detached in front to reconnoitre. When there is any

apprehenſion of being attacked on the march, a brigade of artillery marches at the head of each column preceded by the van-guard of the column. Accordingly as the ground on the flanks is open or ſtrong, they are covered by columns of infantry or cavalry.

In a retrograde movement towards Q, the camp-colour-men and new camp guard march firſt; then the artillery and baggage followed by the army, diſpoſed in as many columns as poſſible, in order to ſhorten the line of march: each has it's rear-guard. In an open country, the light cavalry forms the rear-guard of the army; and in ſtrong cloſe countries, the infantry. When a movement is made by either flank, there are generally as many columns as the army was encamped in lines: the column of artillery and baggage marches on a high road behind the rear line, and is eſcorted by a ſtrong detachment. The light troops march between the firſt line and the enemy, to give timely notice of their approach. In this manœuvre, if the firſt line march along a high road, and the artillery be diſpoſed according to the order of battle, the guns ſhould follow each other in file, and the tumbrils form a ſecond line parallel to them, when the breadth of the road admits of it; but in narrow roads, they ſhould follow the guns: if the enemy advance to attack the army, the tumbrils ſhould be diſpoſed in a ſecond line behind the guns, in order to be ready for action.

226. If the army in marching from the camp A towards B muſt paſs through a defile, and the enemy is poſted on the other ſide, the mouth of the defile ſhould be occupied by ſome grenadiers and other choſen troops, with a few pieces of cannon; under favour of which, the column on coming out of the defile may deploy in order of battle.

When there is a neceſſity of croſſing a river by a bridge, and the enemy is at hand to diſpute the paſſage, ſeveral pieces of cannon ſhould be planted on the bank of the river to the right and left of the bridge, ſupported by ſome battalions, under cover of whoſe fire the army may croſs the bridge, and form in order of battle on the other ſide. Intrenchments thrown up to protect the army in paſſing the bridge, ſhould be lined with cannon and muſquetry. Whenever the river is ſo broad as to render the fire from the oppoſite bank of no effect, an intrenchment ſhould be thrown up, and embrace a large extent of ground; the better to enſure the ſafety of the troops.

The

The army that attempts to paſs through defiles, or croſs bridges in the face of an enemy, ought to be greatly ſuperior in number.

227. An army in retiring from the camp A towards Q, is under a neceſſity of paſſing through a defile, and the enemy is at no great diſtance; the defile ought previouſly to enlarged to render the march more ſecure: when that is impracticable, ſome choſen infantry with a few pieces of cannon ſhould be poſted on the ſides of it. In caſes of particular danger, a ſtrong entrenchment muſt be thrown up at the entrance of the defile, or at leaſt a chain of redoubts at proper diſtances from each other, lined with cannon and muſquetry; the army ſhould then retreat by night, and draw up in order of battle after having paſſed the defiles, to receive the artillery that covered the retreat; and the infantry that was left in the intrenchment will form the rear guard.

When the army in its retreat muſt croſs a bridge, a detachment ſhould be ſent forward to throw up an intrenchment to cover the bridge; a large body of infantry thrown into the work before ſun-ſet, and cannon planted on every point on the other ſide of the river that flanks the intrenchment. During the night, the remainder of the army ſhould croſs the bridge, and draw up on the other ſide of the river in order of battle, to receive the corps of infantry that was left in the intrenchment; and when the whole has paſſed, the bridge ſhould be broken down. This manœuvre ought never to be practiſed but in caſe of neceſſity, unleſs the intrenchment can be made of a very reſpectable profile.

## CHAP. VI.

### Of Battles and general Engagements.

228. AN order of battle is the moſt advantageous diſpoſition of the battalions, ſquadrons and artillery, that compoſe an army, relatively to the nature of the ground, the number of each ſpecies of troops, and the ſtrength and poſition of the enemy: hence it is eaſy to conceive, that the diſpoſitions and combinations of troops may be infinitely varied; but as it would be foreign to our purpoſe to enter into a particular

ticular diſcuſſion, I ſhall only endeavour to give a few general ideas on the ſubject.

229. All orders of battle may be reduced to two, the *parallel* and *oblique*; and each of theſe may be either offenſive or defenſive.

In the *parallel* order, the troops are ſo diſpoſed, as to bring the whole extent of the front line into action; this order was principally practiſed in the wars of the preceding centuries, particularly in level and open countries.

In the *oblique* order, a part only of the front line is engaged, the remainder being kept in reſerve; this is performed with the right or left wing, or with the centre: or with the two wings reſerving the centre; it is then termed the *double oblique*.

An army may either attack or be attacked; a general may from ſome particular advantage ariſing from the nature of the ground, combined with the diſpoſition of the troops, be induced to ſtand an attack: as in the two following caſes;

1. When the troops are drawn up in a poſition naturally ſtrong, where they may receive the enemy's attack, and ſeize the firſt favourable opportunity of acting offenſively.

2. When from the nature of the poſition, the defendants can throw in a fire ſo much heavier than that of the aſſailants, as to give a moral certainty of repelling the attack with great loſs to the enemy, and but little to themſelves: theſe caſes excepted, it is very hazardous to receive battle in a poſition merely defenſive.

The oblique has by the moſt able generals been preferred to the parallel order, whenever the ground admitted of it; ſince it affords an opportunity of diſplaying the moſt maſterly and conſummate knowledge of tactics, and is the beſt adapted to an inferior army.

230. From the definition of the ſeveral ſpecies of troops (Chap. 1.), it is eaſy to imagine a variety of orders of battle adapted to certain ſituations: but the primary object of every general ſhould never be loſt ſight of; viz. of providing for the ſecurity of his own army before he attacks the enemy: wherefore the diſtribution of the troops and the figure of the order of battle ſhould form a kind of a moveable fortification, where all the parts mutually cover and defend each other; and each ſpecies of troops ſhould be poſted in the preciſe ſpot where they can act with the greateſt energy, and occaſionally change

change their operations from defenſive to offenſive: cavalry for inſtance, ſhould be poſted on level and open ground, that they may perform the neceſſary evolutions without impediment or embarraſſment (189).

The artillery ſhould be drawn up in the beſt ſituations for enfilading the oppoſite army with round ſhot (194), or firing caſe-ſhot againſt their front (195). In advancing with the line of the army, the ground in front ſhould be level and open (192): this circumſtance is not very material when the army is not to advance, but receive the enemy in their preſent poſition; it will then be ſufficient, if their rear be ſecured by ditches or other obſtacles againſt a charge of cavalry.

Finally, the infantry which is the ſoul and ſtrength of every diſpoſition, will be advantageouſly poſted when they are drawn up three or four deep behind fences or hollow ways, whence they can keep up an inceſſant fire and manœuvre freely; or ſome paces behind the creſt of a riſing ground, which may ſerve as a kind of parapet: when they are to advance to the attack, the ground in front ought to be open; and that part of the firſt line which is to charge ought to be formed with very deep files or in column, not expoſed to be taken in flank by the enemy's artillery.

231. The diſtance between the firſt and ſecond lines is 300 or 400 paces; with the corps de reſerve, 200 paces in the rear of the ſecond line; or between the two lines, in which caſe, the diſtance between them is increaſed to 400 or 500 paces. When the army advances in line, an interval of 20 or 30 paces is left between every two battalions, to prevent them from crouding the files, which generally happens when this precaution is neglected; but theſe intervals are unneceſſary when the army is to receive the attack: 8 or 10 paces are left between every two guns. The intervals between the ſquadrons of the firſt line ſhould not exceed nor be leſs than half the front of one ſquadron.

In making a long charge in line, the ſquadrons ſhould never touch each other, from the almoſt abſolute certainty of their being in diſorder before they reach the enemy.

232. (Fig. 12, Pl. 8) A B is an army drawn up in the parallel order of battle, to engage the firſt line of the enemy's C C; and may be ſuppoſed to be acting either offenſively or defenſively.

(Fig. 13, Pl. 8.) The army is drawn up in a parallel order of battle defenſive; in this diſpoſition the right wing

G is ſupported by the artillery A, planted on an adjacent eminence, and covered by ſome battalions B drawn from the ſecond line. The left wing A joins to the village C in which are poſted the guns D ſupported by the battalions F, drawn alſo from the ſecond line.

(Fig. 14, Pl. 9.) The ninth plate repreſents two oblique orders of battle: the cavalry is advanced on the right of the army to attack the enemy; the left of this diſpoſition is defenſive, being ſecured by the height A, on which are poſted ſome battalions B with artillery C, and farther ſupported by the columns D, kept in reſerve.

(Fig. 15.) The cavalry C is on the left of the army in a defenſive poſition; ſince the front line of cavalry being in a line with the ſecond line of infantry is covered by the flank A, formed by ſome battalions, and the brigade of the park. The right wing D of the army is compoſed of the grenadiers and choſen infantry, ſome ranged in column and others in order of battle, in ſeveral lines to march forward to the attack. Before the troops advance, the artillery at B keep up a heavy cannonade, ſeconded by the firſt line. The ſquadrons S, ſtand ready to ſeize the firſt moment of the enemy's being thrown into diſorder to charge.

When two armies engage in one or other of theſe orders, it is called a *pitched battle* or *general engagement*: but when from the nature of the ground, the troops cannot be drawn up in either of theſe methods, but are obliged to engage one after the other in a very confined ſpace, it is termed *an action*. The difference then between pitched battles and actions conſiſts in the iſſue of a pitched battle being always very deſtructive to the army that is routed: whereas in actions, the victory decides but little; though perhaps the loſs of men may be much greater than in a general engagement: for which reaſon, the ableſt generals have endeavoured to avoid actions; and when they have been forced into them, it has been owing to ſome accident, which the moſt ſkilful diſpoſition and wiſeſt precautions could not guard againſt.

The principal maxim is, *to adapt the diſpoſition of the troops to the inequalities of the ground, in ſuch a manner that they cannot be taken in flank; but may be able to attack in front and flank, or at leaſt obliquely the enemy's army*: and *to bring into action a greater number of men than the enemy can oppoſe to them*; this is obtained by drawing up the army with a more extended

extended front, in order to out-flank the enemy; with the infantry four deep to throw in a heavy fire.

The artillery is poſted at the points, whence from the nature of the ground and the enemy's diſpoſition they can do moſt execution.

234. The commander in chief having reſolved to give or receive battle, communicates his intentions to the generals and the commanding officer of artillery; that they may do their utmoſt to ſecond them. If the commanding officer of artillery foreſees that the ſeveral brigades may during the action labour under a deficiency of men to execute the ſeveral neceſſary manœuvres, he ſhould apply for a certain number of additionals to be attached to each brigade; either to aſſiſt in working the guns; levelling obſtacles; filling up ditches; or laying down bridges: for the greater ſecurity, they ſhould be under the command of their own officers and non-commiſſioned officers.

It is ſometimes impoſſible previous to an engagement, to reconnoitre the country ſufficiently, to know the points where the artillery ought to be planted; the commanding officer ſhould in this caſe ride along the front, before the two armies come to cloſe action; and ſubmit his obſervations to the commander in chief, propoſe ſuch diſpoſitions of the artillery as appear the moſt advantageous, and inſtantly execute the orders he receives.

When the armies engage in the parallel order, and conſequently the whole front is brought into action, the commanding officer of artillery, beſide his ſtaff, ſhould be attended by ſome ſubaltern officers, that he may be able to ſend orders to the ſeveral brigades; ſince during the action he ſhould never quit the commander in chief without permiſſion; and then only to examine the ſtate of his brigades, or tranſport himſelf to any ſpot where his preſence may be abſolutely requiſite: it reſts with him to demand extraordinary reinforcements for making a vigorous puſh againſt the enemy, or for ſuſtaining a very lively attack.

235. The officers of the ſeveral brigades having received their orders, diſtribute the artillery-men and additionals to the guns, and immediately open paſſages in the front and flank, that they may be able to move without impediment.

When the army advances in line, the guns are drawn by horſes to the place of action; at the commencement of the action, the ſpare carriages and waggons are placed 250 paces

in

in the rear, not to endanger their being blown up, and a tumbril is kept near each gun with the light waggons. The artillery-men and additionals not actually employed ſhould be ſheltered behind the waggons; without which precaution, many men may be ſacrificed to no purpoſe at the beginning of the action, and the guns become unſerviceable long before it is over.

If infantry and cavalry be ranged in two lines, that the ſecond may ſupport and ſupply the place of the firſt; how much more ought the artillery, which during the whole action is expoſed in the firſt line, to have ſome men in reſerve to ſupply the place of thoſe that are diſabled, that there may be always the neceſſary number for keeping up a briſk fire?

The brigade is divided into two parts, each under command of a ſubaltern; who is to take care that the fire is well directed, and the ſervice carried on properly, and without confuſion: the captain inſpects the whole brigade, replaces the men that are killed or wounded, and makes them bring up another tumbril when the ammunition in the firſt is nearly expended. When the action is likely to laſt long, he ſends to the depôt (222) for more ammunition, and informs the commanding officer of his loſſes and expenditure.

236. To derive the greateſt advantage from artillery, the firing ſhould be briſk and without confuſion; and the utmoſt attention paid to loading and laying the guns, that the ſhot at the ſeveral diſtances may reach the enemy: an officer will ſhew his judgment by cannonading that part of the enemy's diſpoſition, which it is of the moſt conſequence to throw into diſorder; or by firing caſe-ſhot, when the diſtance and other circumſtances permit.

Confuſion in the ſervice of artillery ariſes either from the want of a proper diſtribution of the men; from their awkwardneſs; or from their being ſeized with fear, or a ſpecies of delirium, under the influence of which they are deſirous of firing with the utmoſt precipitation. To prevent which;

1. The artillery-men ſhould be exerciſed every day till they have habitually acquired a ſuperior addreſs in the management of the guns, according to the plan of exerciſe laid down in the ſchool-practice: for if every officer takes upon himſelf to alter the mode of exerciſe, it muſt inevitably lead to confuſion; particularly when the men are changed from one brigade to another.

2. The

2. The men ſhould be poſted to the reſpective guns, each man informed of his particular duty; and the additionals practiſed in dragging them.

3. The officer ſhould ever preſerve an air of coolneſs and tranquility, and employ arguments rather than menaces, to encourage the timid, and repreſs the ardour of the violent; puniſhment ſhould not be uſed but in the laſt extremity.

The guns ſhould fire ſlowly at firſt, by which means the ſoldier not being flurried at the onſet will preſerve his preſence of mind in the heat of the engagement, and perform his duty with coolneſs and alacrity.

237. The brigades follow the movements of the infantry, preſerving the proper intervals. In the mean time, the waggons and ammunition carts, that are in front of the ſecond line, follow the guns at the diſtance of 250 paces, till the conteſt is determined. If the enemy retire, the carriages are brought up and the guns limbered to follow more eaſily the movements of the army: but if the iſſue be unfavourable, the captains commanding the brigades, when ordered to retire, exert every means in their power to ſave their guns, though preſſed by the enemy: with a view to this, they ought to have examined the roads, bridges and other avenues, previous to the action. When all retreat is impracticable, the guns ſhould be ſpiked or rendered uſeleſs in ſome other manner, the ammunition blown up, and the principal articles deſtroyed or carried off.

238. The commanding officer of artillery, who has always remained with the commander in chief, ſhould have foreſeen the fatal moment of defeat, and have given ſuch directions that the guns may not on the retreat, embarraſs the movements of the troops. On the receiving the order to retire, he will cauſe the depôt that is ſtationed behind the ſecond line to move inſtantly, and all the brigades of the firſt line to retire by the roads pointed out to them. He will in perſon repair to the ſpot where there appears to be the greateſt difficulty and danger, that by his ſuperior knowledge and experience he may extricate his officers and men out of the ſtraight to which they are reduced; and as the limbers are ſometimes broken and uſeleſs, he will apply for an additional number of infantry to aſſiſt in dragging off the guns. The brigades and depôt, ſhould repair as faſt as poſſible

poſſible to the place of rendezvous, that the troops may follow without confuſion.

When the army is in ſecurity, the captains ſhould examine the ſtate of their brigade, and make a report of deficiencies to the commanding officer, who makes his demands accordingly; the artificers are inſtantly ſet to work to repair the carriages that are damaged.

## CHAP. VII.

### Of the Attack and Defence of Field Fortifications.

239. TO conceive an adequate idea of the beſt mode of attacking and defending field-works, their conſtruction and uſe ſhould be firſt underſtood: to this end, ſome of the fundamental principles laid down in the Treatiſe on Military Architecture will be here repeated.

The object of field-works is defence: yet the mode of defence is very different from the method of defending regular, or even irregular fortreſſes. Since the latter are amply ſupplied with proviſions and ſtores; whereas field-works are open on one ſide and communicate with the country, by which avenue the troops can always receive ſupplies of proviſions, and are generally attacked without the diſpoſitions and precautions uſual in ſieges.

240. Field-fortifications are conſtructed either with a view of covering an army that wiſhes to avoid an engagement, or ſecuring its retreat; of occupying ſome important poſt, to impede or fruſtrate the enemy's deſigns; or of forming an intrenched camp in the vicinity of a fortreſs, to render a ſiege difficult or impracticable. Theſe fortifications are diſtinguiſhed into natural and artificial: in the firſt claſs, are ranked heights that the enemy wiſh to get poſſeſſion of, at the foot of which are hollows or fences that are commanded: and eminences, houſes, villages and woods near to the camp or field of battle, that may be uſeful as points of ſupport, or as advanced poſts to intrench on.

A poſition on a riſing ground with ſteep banks is ſtrong; and when on the ſide towards the enemy, there be a canal, river, lake, morraſs, quickſand, ſteep precipice or narrow paſs through which the enemy muſt defile before he can attack

attack the camp, it is ſtill ſtronger; indeed ſome poſitions of this nature are found that are impregnable.

241. When the ground is not naturally ſtrong, it is rendered ſo with field-works: this occurs moſt frequently in countries interſected by large canals or rivers, &c. or in mountainous or ſtrong countries, whither an inferior army is compelled to retire from the open champaign country to avoid being ſurrounded and cut off from its ſupplies.

In field-works conſtructed on the flat parts of a ſtrong country, one ſtage of fire is generally ſufficient; but in forts and large redoubts, that are to ſerve as points of ſupport to other intrenchments or as inſulated poſts, there ought to be two ſtages of fire.

In mountainous countries, from the natural advantages of the ſituation, two ſtages of fire may be obtained with little expence or trouble.

242. In the conſtruction of field-works, regard muſt be always paid;

1. To the nature and extent of the adjacent country,
2. To the interior area.
3. To the figure of the works, and the mutual ſupport of the ſeveral parts.
4. To the profiles of the works.

243. Thoſe field-works are the ſtrongeſt, which from natural or artificial obſtacles cannot be approached by the enemy in regular order (242, No. 1): when the intrenchment cannot be made inacceſſible along the whole front, a part of it at leaſt ſhould be made ſo; always keeping in view this maxim that *the flanks be better defended than the front.* The ground before the acceſſible parts ſhould to a proper diſtance, be cleared of trees, hedges, buildings, and every thing that can give ſhelter to the enemy.

244. The interior area ſhould be ſo ſpacious, that all the troops may encamp in good order, and perform the neceſſary manœuvres for defence without being ſtraitened for room. When the army is encamped in one line, 500 paces are left between the intrenchment and the tents for the troops to form on; and when in two lines, this diſtance is increaſed to 800 paces (242, No. 2).

The front of the encampment ought not to be unneceſſarily extended, leſt there be too few men to line the intrenchment: when there are any ditches, canals, precipices or other obſtacles to a free communication between the ſeveral parts, bridges

bridges ſhould be laid and the heights levelled: and the encampment ſo diſpoſed, that the army may move by either flank in the order that may appear the moſt advantageous for gaining any object in view, ſuch as ſeizing an important poſt, &c.

From theſe remarks on field-works it may be inferred, that an officer ought to be complete maſter of the manner of attacking and defending this ſpecies of fortification, before he can be competent to decide upon the advantages or diſadvantages of particular ſituations.

245. Redans connected by curtains is the moſt common figure for field-fortifications in a campaign country: when from the nature of the ground this figure muſt be deviated from, it ſhould be a maxim that *every part be flanked*, that *the line of defence never exceed* 260 *yards*, and even leſs when particularly vulnerable (242, No. 3).

The figure of ſmall forts erected to ſecure the flanks, or ſerve as points of ſupport to the weakeſt parts, or as advanced poſts, muſt depend on the nature of the ground: a covered way before the fort, or a ſmaller fort conſtructed within the larger one will give two ſtages of fire.

There are two methods of fortifying houſes, villages, and other large buildings: the one is to cloſe and barricado the ſtreets, doors and lower windows on the ſide of the enemy and enlarge them on the oppoſite ſide, to give free room for the troops to enter for the defence: the other is to eſtabliſh two ſtages of fire, the firſt from the intrenchment that ſurrounds the village; the ſecond, from the upper windows of the houſes. In tracing the intrenchment, an interval of 30 paces at leaſt ſhould be left between it and the houſes, that the troops who line the works, may not be incommoded by the devaſtation occaſioned by the enemy's ſhot among the buildings. When there is a free communication between the village and the army, the front and flanks only need be intrenched; except it is intended as an advanced poſt, then the work ſhould be cloſed,

246. Field fortifications may be claſſed under three heads (242, No. 4)

The firſt kind is the moſt ſimple, and conſiſts of a parapet 4½ or 5 feet high and 3½ feet thick at the top without banquette: this is thrown up in places which the enemy cannot approach without being obliged to defile; but never on flat open ground, unleſs the army be but little inferior in number to the enemy.

The

The profile of the ſecond kind conſiſts of a parapet $7\frac{1}{2}$ feet high and 6 feet thick with a broad banquette, that the infantry may draw up two or three deep, and the troops at the foot of the banquette be ſheltered from the enemy's fire: the ditch is from $7\frac{1}{2}$ to 9 feet wide and $4\frac{1}{2}$ feet deep. Both theſe kinds of intrenchment are liable to be inſulted; or in other words, expoſed to aſſault without any previous ſteps on the part of the aſſailant.

The profile of the third kind is a parapet from 12 to 15 feet high, and as many thick; with a ditch from 20 to 26 feet wide and from $7\frac{1}{2}$ to 11 feet deep: this intrenchment is ſaid to be ſecure from inſult; as it cannot be attacked but by a kind of regular ſiege, by opening trenches and erecting batteries. A row of paliſadoes fixed horizontally half way up the parapet, or with a ſlight inclination at the foot of it, adds much to its ſtrength. The banquette is from $7\frac{1}{2}$ to 9 feet broad, that the infantry may draw up two deep and maintain a heavy fire, when the ground in front is favourable to the enemy's attempting to carry the work by aſſault.

247. The troops for the defence of the two former intrenchments are diſpoſed as follows:

1. The parapet is lined with one rank of infantry, who keep up the paliſado firing when the ground in front is ſo broken that the enemy cannot approach in order; when the ground is leſs broken, they are drawn up two deep and fire by platoons. When the ground is ſo favourable, that the enemy may adopt whatever diſpoſition appears the moſt feaſible, the infantry are drawn up 4, or at leaſt 3 deep, and fire by word of command from their officers. In this caſe, the two front ranks give their fire, and kneel down to give liberty to the two rear ranks to fire; they then riſe and the whole reload. Of the various methods of parapet firing, this is the moſt ſimple and effectual, and produces more than any other, that ſolidity and conſiſtence which forms the excellence of every body of troops.

2. Beſide the troops on the banquette, there ſhould be ſome poſted in reſerve at a proper diſtance in the rear, to be ready to move to any part where they may be wanted; and behind the points, where the moſt ſerious attack is to be apprehended, a ſecond line of infantry ſhould be formed 300 paces from the parapet; with ſome ſquadrons of cavalry, drawn up in the rear on a

flat piece of ground, ready to charge the enemy, the inſtant they force the intrenchment.

3. In the third kind of intrenchment, the diſpoſition of the troops depends upon the mode of attack: when the enemy makes regular approaches, the ſame regulations are to be adopted as in the defence of fortreſſes. If the enemy attempt to carry the work by aſſault, the troops ſhould be drawn up 3 or 4 deep on the banquette to throw in a very heavy fire, in order to make him repent of his temerity.

248. The diſpoſition of artillery in the two firſt ſpecies of field fortifications depends on the nature of the ground, and the order in which the enemy approaches. The general rule is,

1. To poſt the artillery at the parts where the moſt ſerious attack is apprehended, leaving to the infantry the defence of the other parts.

2. If the enemy advance in column, guns are placed on every point that can enfilade it; and if in line, caſe-ſhot is fired from all the guns that bear directly on his front: ſome others are brought to bear obliquely with round ſhot. An inceſſant firing is kept up, till he is obliged to retire out of gun-ſhot to rally: then the firing is ſuſpended; and every thing prepared for giving him a warm reception when he returns to the attack.

3. When the ground is ſo favourable to the enemy, that he can by manœuvreing alter his diſpoſition at pleaſure and keep the defendants in doubt which part he intends to attack; ſome guns are kept limbered and loaded, that they may be inſtantly drawn to the point of the greateſt danger.

249. In attacking an intrenched camp with a profile of the firſt or ſecond kind, the flanks ſhould be firſt attempted; but if their profile is, as it ſhould be, of the third kind, the troops muſt advance within 700 or 800 paces of the front of the intrenchment in the parallel order, and then make the attack in the oblique or double oblique order, taking care not to preſent the whole front to the fire of the intrenchment, unleſs the enemy weaken ſome part not attacked in order to reinforce thoſe againſt which the attack ſeems directed.

When any defect in the works, or the interior of the camp, that embarraſſes the troops in their manœuvres is perceptible, the weight of the attack ſhould be directed againſt that part; otherwiſe

otherwiſe; the greateſt efforts ſhould be made at the point where the exterior ground preſents ſome advantages: the infantry being diſpoſed in ſeveral columns, connected with other troops and ſupported by a ſecond line of infantry, with the cavalry drawn up in the rear, ready to gallop into the intrenchment the inſtant the infantry have entered and opened breaches large enough to admit them.

The previous diſpoſitions being made and the ſignal given for the attack, the troops march forward in quick time; ſince it is only by advancing rapidly, that the defendants can be deprived of the advantages they have over the aſſailants: for the fire of the latter is, at the beſt, but uncertain; while they are expoſed to a very heavy and well-directed fire from behind the works: common ſenſe and experience agree on this point.

250. In the aſſault of field-works, it depends on the poſition of the intrenchment and the nature of the ground where the troops form, whether the whole or a part only of the artillery can be employed. The general rule is for the artillery to keep a very heavy fire previous to the advance of the troops, that they may meet with leſs reſiſtance and penetrate more eaſily. The principal caſes in which artillery is uſeful in this kind of attack are:

1. When the artillery of the works can extremely annoy the aſſailants, a ſuperior number of guns are brought up to ſilence them; and when there is any commanding ground at 200 or 300 paces from the works, ſome infantry is poſted on it to throw in as heavy a fire as poſſible (199).

2. When there are any forts or redoubts with two ſtages of fire within the works, the fire of all the artillery is directed againſt them to throw the troops that defend them into diſorder; the inſtant this is perceived, the infantry advance rapidly to the aſſault. Red-hot ſhot and howitzer ſhells filled with combuſtibles are thrown into intrenched villages or houſes to ſet them on fire; it ſhould be laid down as a maxim in the attack of towns or villages, *never to let the infantry advance before the artillery has thrown the garriſon into confuſion.*

3. Any ground in the vicinity of the intrenchment, that enfilades or commands it, ſhould be occupied by a ſufficient number of guns to take full advantage of this favourable circumſtance.

4. In the three preceding caſes the diſtance of the guns from the works ſhould be from 240 to 340 yards: and when very much expoſed to the enemy's muſquetry, they may be in ſome meaſure ſheltered by caſks filled with earth, or with the doors and windows of the neighbouring houſes: Some officers from an abſurd and falſe principle of honour have diſregarded this mode of covering the artillery; but thoſe who conſult the real honour of a ſoldier will know, that it conſiſts in advancing the intereſts of their country in the moſt certain and expeditious manner; it is therefore the firſt duty of an officer to cover his men as effectually as poſſible. Some guns ought to march in the rear of the column to ſeize any opportunity of acting to advantage.

251. Artillery is alſo employed in the attack of intrenched poſts, in the following caſes:

1. When the intrenchment is of great extent; as lines of circumvallation, and expoſed to inſult: ſome guns are ſent with a body of infantry to make a falſe attack during the night, in order to cauſe a diverſion of the enemy's troops: the falſe attack is made at a diſtance from the real one, and commences ſome hours before it with a very heavy fire.

2. When the profile of the intrenchment ſecures it from inſult, a kind of irregular ſiege is carried on with batteries and trenches: theſe attacks are generally directed againſt the flanks of the intrenched camp, or ſome ſaliant point.

3. In battering bridges built of boats, and covered by redoubts or intrenchments, ſome guns are brought to the edge of the river, whence they can bear on the bridge; and if the oppoſite ſhore be lined with muſquetry or artillery, a ſuperior fire muſt be directed againſt it, to cover the guns: when the intrenchment is injudiciouſly conſtructed, the infantry after the fire of the artillery has continued for ſome time, ſhould advance and ſtorm it.

4. When the enemy having laid a bridge of boats, endeavour to paſs the river; the troops and artillery that are to diſpute the paſſage, form oppoſite to the bridge, to enfilade the enemy, who having croſſed the bridge in column, will endeavour to deploy in order of

of battle; ſome guns are alſo planted on the bank to cannonade the bridge: and if the enemy cover his paſſage by a fire from the oppoſite ſide, a ſuperior fire muſt be eſtabliſhed. It may be remarked here, that whenever a bridge is to be attacked, or the paſſage of it diſputed, and there are guns on both ſides of the river, if the two banks be not on the ſame level, the troops on the higheſt bank will have the advantage, when the river is not leſs than a muſquet ſhot acroſs.

## CHAP. VIII.

### Of the Quarters of an Army.

252. IT is cuſtomary to put the troops into winter quarters towards the end of autumn; and in ſome countries, into ſummer cantonments during the great heats of that ſeaſon. They are lodged in the towns and villages, and diſtributed according to the order of battle in which they are encamped; that is to ſay, the troops that compoſe the firſt line are quartered in the houſes neareſt to the enemy, and thoſe of the ſecond in the towns in the rear; regard is alſo paid to the poſition of the wings and centre, ſo that the troops may on occaſion march forward to the ground that is fixed on for their general rendezvous, without confuſion or danger of croſſing each other in the march. The quarters are more or leſs extended in proportion to the diſtance between the two armies, and there is generally a river or defile in front.

253. The brigades of artillery are generally quartered together in ſome city or town in the ſecond line, with a body of infantry to cover them.

At every halt during the campaign, the damages were repaired as far as circumſtances would admit; and advantage is now taken of the ſummer cantonments, to examine and put every article in a complete ſtate of repair, that on any emergency the brigades may be inſtantly ready: the ammunition, &c. is left in the waggons, and the park formed in the proper order, that the horſes may be harneſſed without confuſion. When the ammunition is carried on beaſts of burthen, it is unloaded and lodged in ſome building not expoſed to fire, and ſpacious enough to contain it without

mixing

mixing the ſeveral ſpecies together. The officers, non-commiſſioned officers, artillery-men, -drivers, conductors, and horſes are quartered in the houſes contiguous to the park, with a proper guard; particularly in conquered countries. The commanding officer of artillery having been previouſly advertiſed by the commander in chief, of the poſition each brigade is to take up in the field of battle, and of the route by which they are reſpectively to march, examines the roads and ground attended by his captains, and orders the neceſſary repairs to be made to facilitate the march: he explains to his officers the intentions of the general, that they may be enabled punctually to execute the orders they receive, whether by expreſs or concerted ſignal; in the latter caſe, ſome attentive men are poſted day and night to obſerve the ſignals.

254. When in front of the line of quarters, or on the only road by which the enemy can approach the cantonments, there is any poſt or commanding ſituation; it ſhould be occupied by a detachment of infantry, ſupported by one or two brigades of artillery, that it may be able to hold out for ſome days, and give time to the army to aſſemble and march to its relief. The officer who commands theſe brigades will conſider attentively the nature of the poſt, and the adjacent country, and judge whether it be expoſed to a coup-de-main; and whether it can be ſtrengthened by any additional works: he will communicate to the commanding officer of the poſt, his ideas upon the plan of defence, and poſt his guns at the moſt important points, with a proportion of ammunition in caſe of attack.

255. At length, the ſeaſon for military operations being over, and the commander in chief having ordered the army into winter quarters in the moſt convenient and plentiful country, that they may recover themſelves from the fatigues of the campaign; the brigades of the artillery move towards the place of their deſtination under the eſcort of a body of infantry or cavalry, marching and parking as before directed. Being arrived at their quarters, which ſhould be covered from every attempt of the enemy, the ammunition is lodged in the magazines, the carriages put under cover, and the neceſſary repairs inſtantly begun: during the winter, attention ſhould be paid to the comfort of the men, and the forage of the horſes, that the whole may be able to take the field in the enſuing ſpring with recruited ſtrength and vigour.

FINIS.

## ERRATA.

| | | | |
|---|---|---|---|
| Page | xiv | Line | 25, *for* d'Oil *read* d'Œil |
| —— | xv | —— | 10, *for* adopted *read* adapted |
| —— | 6 | Paragraph | 18, *for* cinders *read* aſhes |
| —— | 10 | —— | 37, *for* fabric *read* manufacture |
| —— | 85 | —— | 175, *for* ·243 *read* ·0303, *and for* 587 *read* ·0606 |
| —— | 91 | —— | 183, *for* 472, &c. *read* 400, &c. |
| —— | 157 | —— | 126, *for* $n\,x$ *read* $n \times$ |
| | ditto | —— | ditto, *for* 1444300 *read* 1499800 |
| —— | 158 | —— | 128, *for* 2460 *read* 2490, &c. |
| —— | 302 | —— | 122, *for* 40 *read* 30 |
| —— | 336 | —— | 178, *for* counter-attack *read* counter-approach |

*Plate 1.st*

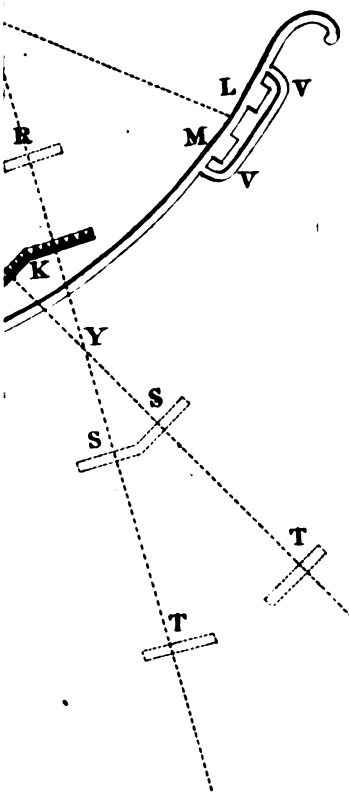


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*Plate 2nd.*

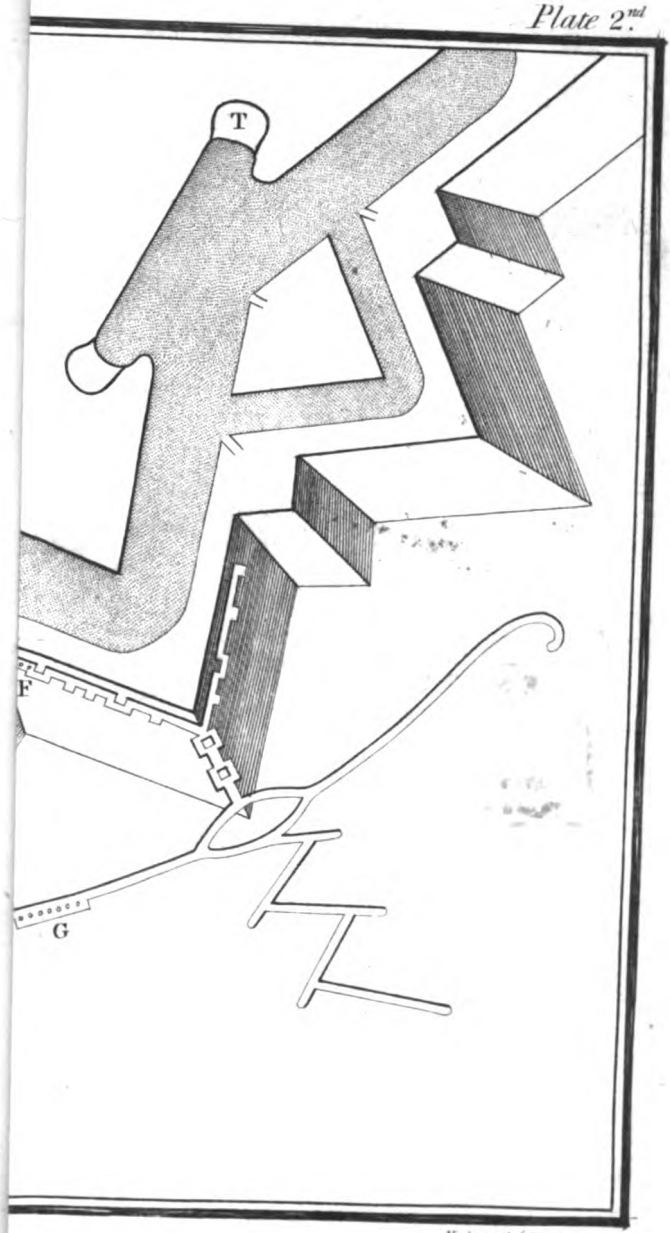


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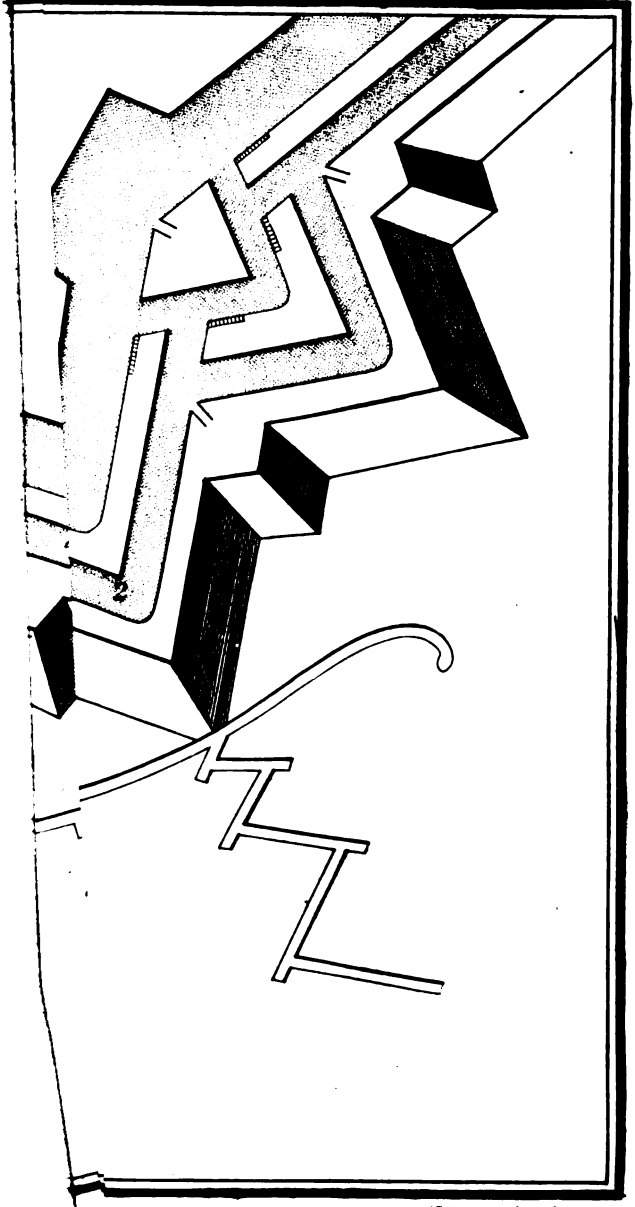
Plate 3d.



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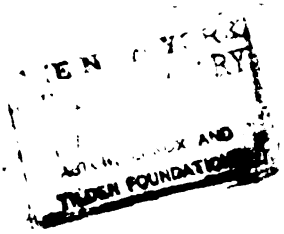
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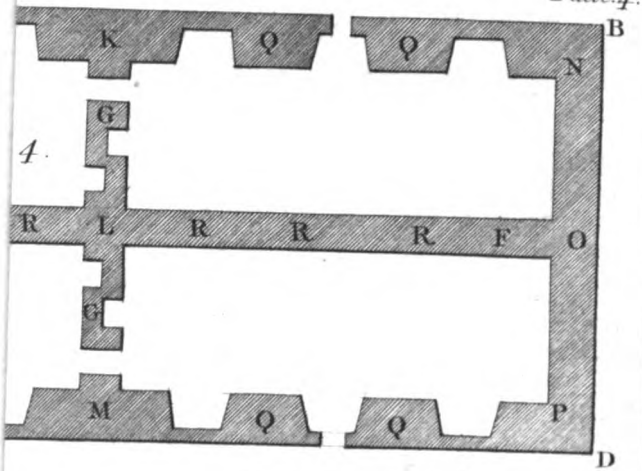


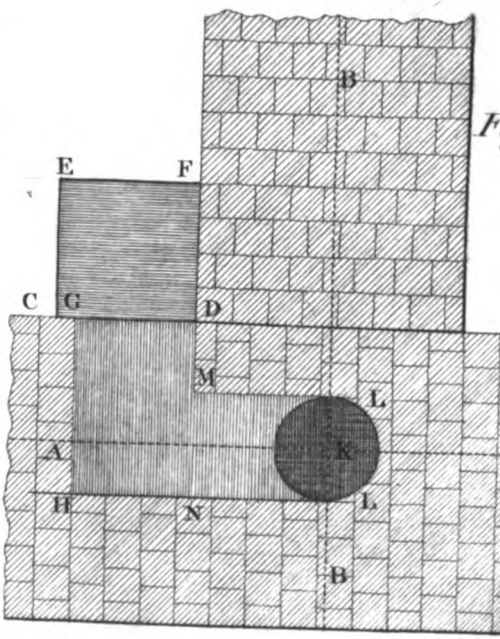


Fig. 8.

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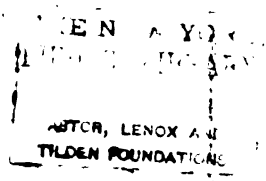
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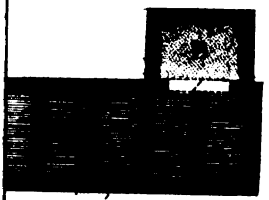

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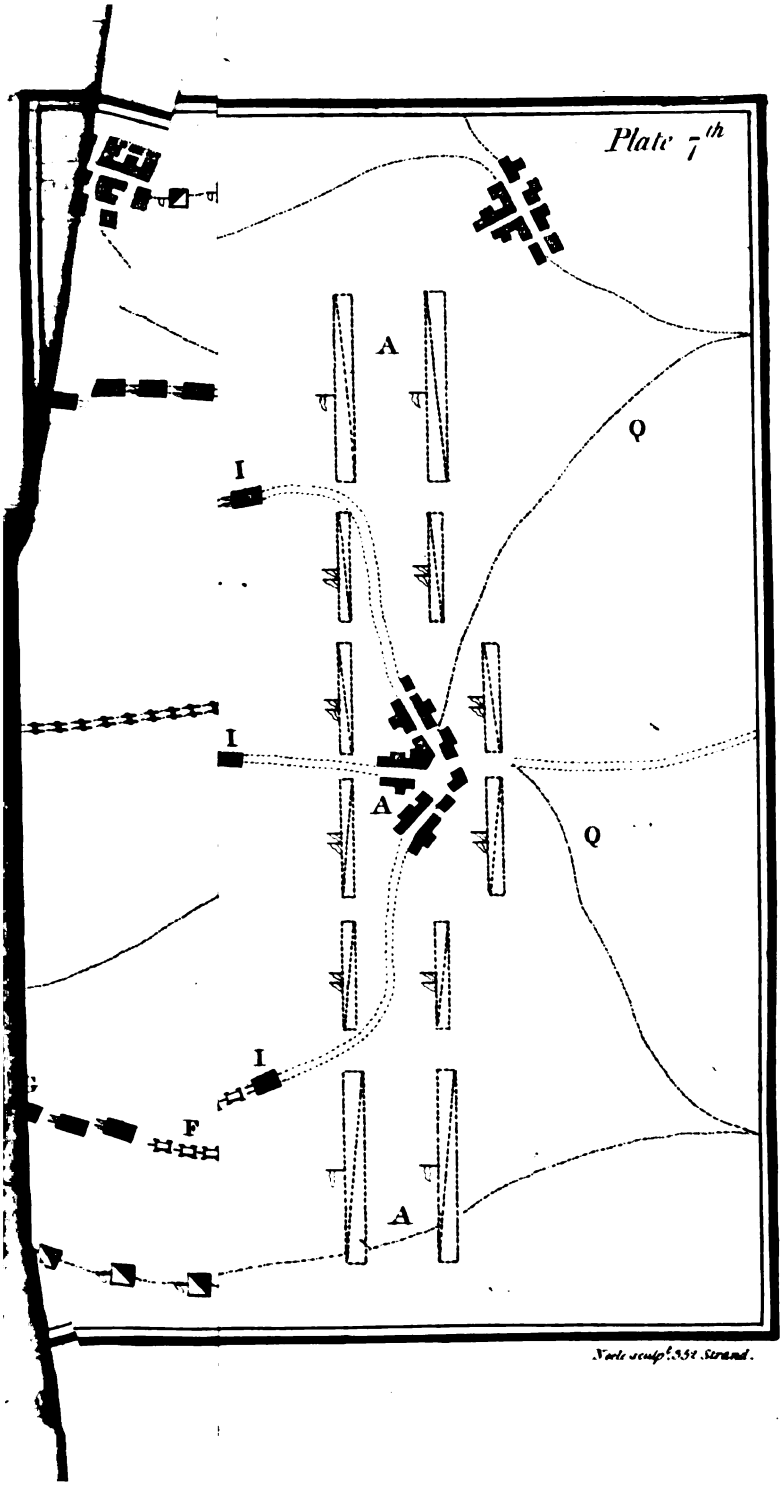


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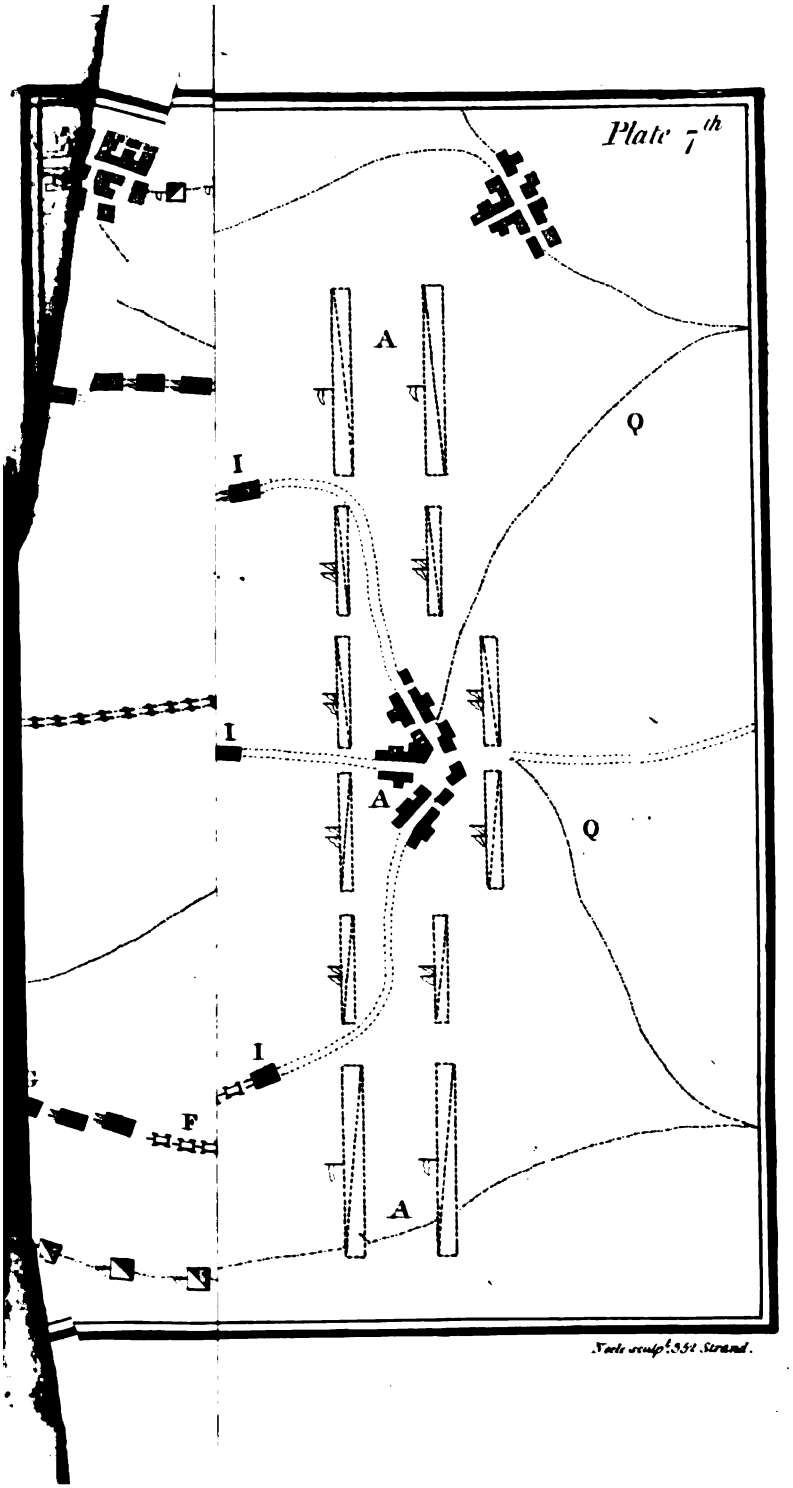
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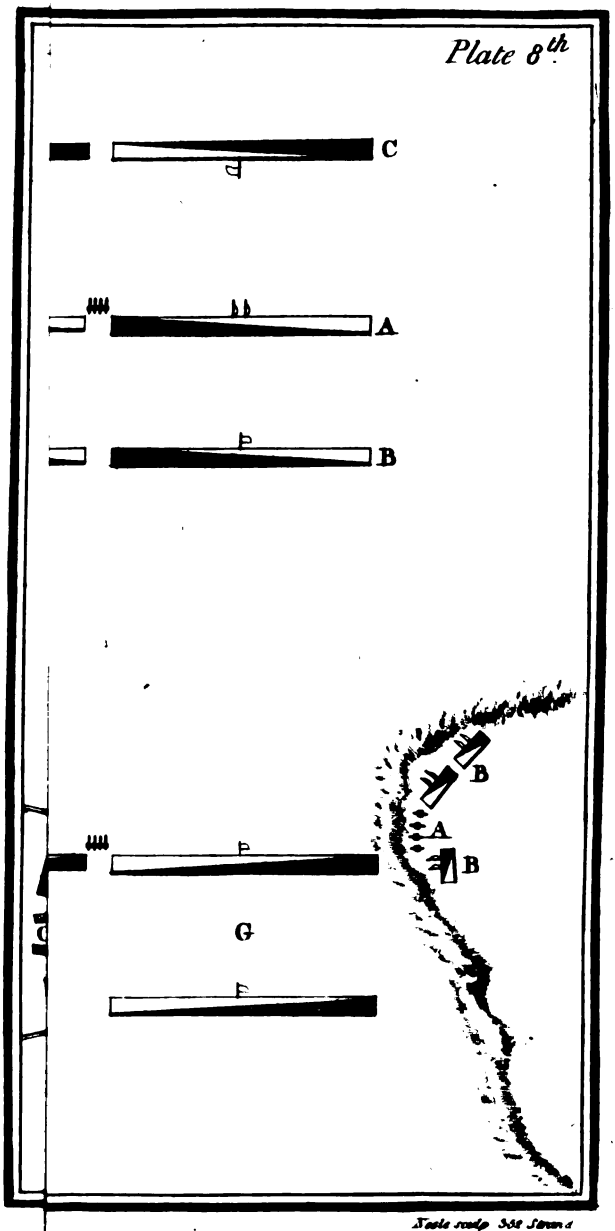
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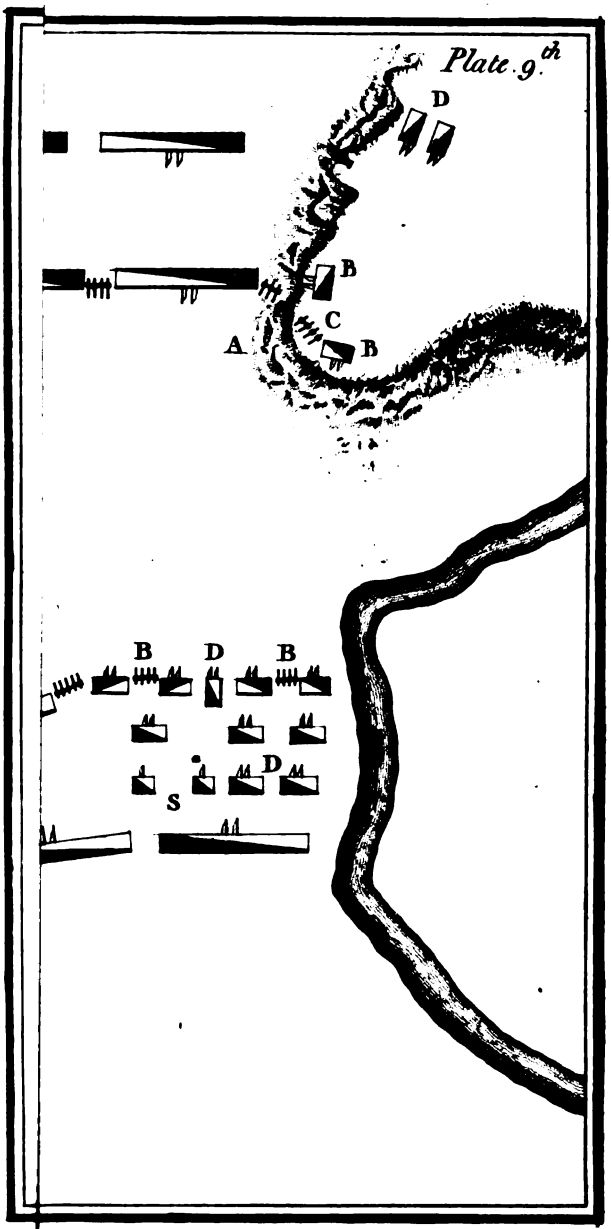
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